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MODERN SCIENCE *and* PEOPLE'S HEALTH

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SCIENCE IN A DEMOCRACY

Benjamin C. Gruenberg, Ph. D.

CHAPTER I

SCIENCE IN A DEMOCRACY

On the 8th of May, 1794, Antoine Laurent Lavoisier, a great French scientist, was guillotined together with some other persons who were obnoxious to the powers for the moment in control of affairs in Paris.

Lavoisier was a chemist. He carried on many ingenious experiments, including some on mice, to find out what connection there is between air and fire—between the air used up in a fire and the heat given off by the flame—and what air has to do with keeping alive. He was the first person in the history of the human race who had a real understanding of what combustion means—the process of burning, whether in the extreme form of violent explosion, in the generous flame of a log fire, or in the slow and steady oxygen consumption of living animals.

Man had used fire for many thousands of years; without it he would have probably remained a savage. Man had improved upon the use of fire in a variety of ways. Long before Lavoisier's time he had invented stoves for cook-

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ing, candles for lighting, fire-places for heating. But it remained for Lavoiser to find out what the process of burning was; and Lavoisier found out by means of experimentation. His experiments laid a foundation for our modern sciences of chemistry and physiology and have therefore been of the highest significance for mankind.

"The Republic Needs No Scientists"

It was not for his scientific knowledge that Lavoisier was executed, although that might have been added to the charges against him, if those in power had understood. Any new discovery lays one open to suspicion. Prometheus was condemned to a life of suffering for having stolen fire from the gods and for having bestowed it upon man. Lavoisier was eliminated in accordance with a very simple formula: *the Republic has no need of scientists.*

In the years since that event, more and more people have learned to value what Lavoisier did; and whether our sympathies are with the Republicans of revolutionary France or with the Bourbons, we must regret the execution as wanton and cruel. The episode has been frequently used to discredit not only those who were actually responsible for the execution, but democracy in general. While there has always been need of scientists, of men who know, scientists have not always chosen

to use their science for the general welfare. They have often enough devoted their services to those who could value and compensate. When the revolutionists said that the Republic had no use for scientists, they were expressing what was then the common opinion. The scientists had done nothing for the Republic. Science, which is another name for Knowledge, means Power. Democracy has raised the question who should wield power, and for what purpose power is to be used.

Democracy is Humanitarian

We need not delay for a definition of Democracy. Democracy means many things, perhaps many conflicting things. It represents the aspirations of multitudes. Toward the end of the eighteenth century, Democracy was the ideal that inspired masses of people clamoring for a new consideration and for recognition never before accorded them.

The revolutions of the period were culminations of the humanitarian movement of generations preceding. They meant a revolt against autocracy, against oligarchy, against tyranny. Notwithstanding the cruelties and carnage involved, they represented a new emphasis upon the value of human life. They were meant to reduce the harshness of human relations, the inhu-

manity of institutions. They were declared to give man new liberties, new religious opportunities, new intellectual opportunities. In their insistence upon political liberty they emphasized the virtue of unhampered opinion; although they did so by neutralizing all opinion, by setting up the doctrine that all opinions were of equal validity.

Liberty and Science

The overthrow of political authorities liberated inquiry. People now have the right to ask questions, to express dissent from prevailing doctrines, to challenge authorities and officials. These conditions, brought about by the emergency of democracy, are in turn essential to the growth of science.

Science depends upon freedom of inquiry. Where beliefs are established by authority of State or Church, inquiry is hampered or is confined to problems of no great moment in the every-day life of the people. The scientist must not only be free to ask questions, he must be free to challenge prevailing doctrines and even the official acts of those in authority. Science depends upon the free expression of thought and is hampered where such free expression is restricted, upon whatever grounds. Those who investigate must be free to communicate with one another for the clarification of their thought,

as well as to communicate to the public the results of their findings. It is because science results from untrammelled discussion and experimentation, not from deductions resting upon authoritative doctrines, that democracy has tended on the whole to favor its growth.

Autocracy and Science

There had indeed been scientific investigations before the rise of democracy. They had directed themselves for the most part, however, toward problems that did not lie close to the every-day concerns of masses of people, or to the interests of the ruling classes. Throughout the centuries preceding the democratic revolution, power was exerted to repress the scientist, wherever he approached too closely the authoritative doctrine. This was true in physical sciences, as in the imprisonment of Galileo, no less than in the biological sciences, as in the exile of Vesalius. Moreover, science made rapid strides in the autocratic countries like Russia and Germany during the nineteenth century. Again, however, the problems with which the scientists were free to deal were not too close to the interests of the ruling class. The political science in these autocratic countries was hardly more than a rationalized scheme for justifying the doctrine of divine right. Throughout the area of western civi-

lization, it is only those isolated spots which have not been affected by main currents of thought that still witness a conflict between the methods and findings of science and prevailing religious or political doctrines. In no important region does the ruling class place any obstacle in the way of scientific investigation.

The Industrial Revolution

The industrial revolution itself, which is in many ways closely tied up with the political revolution, rested upon the application of a few scientific principles in the field of mechanics. The invention of power engines and of labor saving machinery became possible after physical science had reached a certain stage of development. The extension of modern industrial methods to the chemical industries and to agriculture awaited in turn the further extension of the scientific methods into new fields.

These radical changes in our industrial processes have progressively brought about tremendous economies, and these in turn stimulated still further the growth of science. There has been the release of workers through increased productivity of industries. There has been an opening up of resources not hitherto accessible, both through the development of transportation facilities and through the development of

machinery for breaking up minerals, for digging, for chemical disintegrations, and for the utilization of by-products. There has been a vast increase in the facilities of communication, both through the printed page and otherwise. There has been the stimulus of special problems arising out of industries and carrying the promise of substantial material reward in addition to the other motives that normally drive people into scientific careers. While these factors have not all been directly dependent upon a democratic form of social organization, they have all been facilitated by democracy, just as in turn the results of these industrial advances have promoted the democratic spirit even in the older autocratic countries.

Science and Ignorance

What we call science has grown at a tremendous rate during the past century. It has grown at an accelerating rate. More knowledge was accumulated during the last quarter of that century than during several preceding centuries. More knowledge has been gathered during the past decade than during several preceding decades. And every time a scientist makes a discovery, or solves a problem, or answers a question, he opens up new unexplored territory, new problems, new questions. That is why the body of *what we do not know* is growing so fast. That is why only

the ignorant person is still afraid to say "I don't know."

It is no reflection on Science to say that it has made us aware of how much we do not know. Indeed, that has been one of the most valuable contributions it has made to human welfare. Thousands of specialists and experts in various fields, recognized by their colleagues as experts and authorities, are now able to say "I don't know" without embarrassment. They need no longer affect omniscience. And thousands of people who are not experts in anything whatever are now able to say of another "He doesn't know" without disparagement. Informed men and women no longer expect any one person to know everything.

This state of affairs is a tremendous advance over that in which it was tacitly assumed that everything knowable or worth knowing was already known by somebody, by the experts or by the "educated." It is a tremendous advance because it makes possible the displacement of revered opinion and superstition with real knowledge. No informed person need be ashamed to acknowledge his ignorance. Nobody need be ashamed to ask questions. And when people ask questions instead of pretending to know the answers, there is some hope that they will really find out.

The growing realization of our ignorance—

that is, of our need for knowledge—has made science reputable.

Opinion versus Knowledge

Notwithstanding these great advances in science made possible by the growth of democracy, the democratic idea has in turn developed serious obstacles to the further growth of science and to its applications. The first of these obstacles to scientific thinking is the emphasis which democracy places upon the sacredness of private opinion. We have carried over from the religious and doctrinal controversies of earlier times a certain sensitiveness—and intolerance. Under the Constitution we have, indeed, some sort of right to hold and to voice opinion on every conceivable subject. What value that right has in the presence of ascertainable knowledge, or what reciprocal obligations such right involves, nobody can tell. Most people have no opinion whatever on the desirability of adding a magnesium alloy to the filaments in our electric light lamps in order to increase the light or reduce the cost, or for any other purpose. They are ready to say frankly they do not know, or to shrug their shoulders and pretend they hadn't made up their minds yet. Most people would not venture an opinion on the feasibility of producing transparent lead, or steel-hard aluminum, or syn-

thetic proteins. Yet these same people insist upon the right to hold opinions (and to act according to these opinions) upon such highly technical questions as the efficacy of vaccination, the value of serums, or the causation of cancer. The mass of people in a democracy do not know where opinion is warranted and where reliable knowledge obtains. It is the fashion in a democracy to hold opinions and to disparage the expert.

Freedom in the Use of Words

It has been said that the dreams of one generation become the realities of the next. The imaginative Jules Verne described what was in his time a preposterous submarine; today we shrug our shoulders at submarines and turn eagerly to hear of a more startling invention. The author of *Alice in Wonderland* must have chuckled to himself when he invented the absurd notion of making words mean what we wish them to. Yet our democracy has solemnly decreed to individuals this prerogative of a free people. Perhaps it would be fairer to say that many individuals adopt the right to use words with such meanings as they like to impose upon them. A classic example of this folly is found in the propaganda against the use of the experimental method in dealing with medical problems.

In 1912 the Japanese scientist Hideyo Noguchi, working at the Rockefeller Institute in New York, developed a method for detecting the presence of a dormant syphilitic infection. While it was possible to determine the existence of actively progressing syphilis, not only by the patient's symptoms, but by the Wassermann test of the blood, there was no means of detecting what is called a latent infection, i.e., one in which the microbes are present in the body but are temporarily restrained from activity by the individual's natural resistance. Such quiescent infections are likely at any time, under circumstances of lowered vitality, to become active severe infections, and it was extremely desirable for the physician to be able to ascertain the presence of the germs in the body and begin treatment before they could have opportunity to invade the vital organs and do irreparable injury.

Noguchi's test was based on the same principle as von Pirquet's skin test for tuberculosis. Noguchi found that when an extract of killed syphilis germs was introduced into the skin of healthy rabbits and of rabbits infected with syphilis, a characteristic reddening appeared on the skin of the syphilitic rabbit but not on that of the normal animal. The next step was to determine whether the skin of syphilitic human beings would show a similar reaction to the injection of the extract. The extract was furnished to a

number of physicians who were interested to ascertain its effectiveness in determining the nature of disease in persons whose blood had failed to give indication of syphilis by the Wassermann test, but whose ailments were suspected to be of syphilitic origin. A large number of doctors, nurses, and medical students volunteered to serve as "controls" for the test, for it was necessary to compare the results of injecting the extract into healthy persons with those obtained in cases of syphilis. In institutions and hospitals for children, where it was desired to detect the presence of congenital syphilis, the skin test was made on the entire group, those who were apparently non-syphilitic as well as those who showed definite signs of syphilis. These tests were of course not made by Noguchi himself, but by physicians in charge of the patients tested. These physicians reported their results to Noguchi, who states in his article that "through the courtesy and collaboration of . . . [list of physicians], I was enabled to apply the skin reaction to a number of human cases". He also states in his article that the syphilis germs were first killed by heat and then further treated with carbolic acid, and that the extract was finally tested for its harmlessness before being used for human injection.

We are not now concerned with the efficacy of the luetin test. We are concerned with the

mental perversion that is possible when the strong wine of liberty rushes to the head. "Noguchi infects fifty babies with the germs of syphilis!" With this statement certain persons can make it their business to arouse horror and a sense of outrage. Some have been repeatedly challenged to repudiate or to substantiate the frightening tale: but they do not feel called upon to repudiate it, for apparently they have a sincere belief in its truth; and they feel that they can adequately substantiate it by quoting from Noguchi's own reports—certain selected fragments.

Suppose we protest, Noguchi did not inoculate children—with syphilis; the answer comes back, he said himself that he injected the stuff—see page so and so. But that was not the germs of syphilis, we insist; and we are told that there is no use quibbling about words! Noguchi said he made a culture, and he did something with it, and then he injected—see page so and so.

Here are people who go about their daily affairs without legal restraint, misrepresenting an important scientific research, and justifying their misrepresentation on the democratic assumption that they have a right to make words mean what they want them to. They are not going to ask Noguchi what *he* means by luetin; no, they insist upon their right to decide for themselves. They are not going to ask the doctor what he

means by *infecting with syphilis*; they can use their own judgment.

Right of Private Judgment

Analogous to this abuse of a supposed right is another prevalent confusion, also in the field of medicine. This is the wanton use of the word *pus* as a substitute for *vaccine* and for *serum*. It may seem to many of us far from "natural" to inject into the system an animal product of any kind. Men of eminent intellect, like Herbert Spencer and George Bernard Shaw, have been unable to reconcile the practice of vaccination with their notions of the fitness of things. Some people have sentiments against the introduction of animal matter by way of the mouth. We must nevertheless consider a practice in terms of what it actually is, and not in terms of the offensive language that we may attach to it.

To most people the word *pus* means the product of a septic or festering wound, and pus contains both the germs or bacteria that bring about the festering, and some of the products of this process. "Putrid pus" is therefore well calculated to arouse disgust in many people, and sometimes also fear. Now, the word *vaccine* is a technical term and is used to include a variety of products that have been found effective in bringing

about a more or less lasting immunity to some specific infection. The most commonly used vaccine is that for protection against smallpox infection. This is obtained from the lymph, the clear exudation on the prepared surface of a calf's skin, and is neither a *pus*, nor putrid.

Serum is another technical term, having a general and a special meaning. In its general sense, serum is the clear liquid that remains when a clot has formed in blood. In its special sense, a serum is this clear liquid having special properties, as, for example, when obtained from an animal that is suffering from a given disease or that has recovered from a disease.

To use any of these words interchangeably is confusing enough; but to use a common word that is charged with feeling as a substitute for technical terms that should be considered calmly and objectively, is to commit an outrage upon the intellect. And yet this is being constantly done—in the name of liberty! The argument for this abuse is very simple: we ordinary people have no use for the subtleties and refinements of the experts; we don't want to split hairs; common words are good enough for us.

A vulgar example of this kind of abuse of language in another field is the smart exclamation of a certain type of vegetarian, "I wouldn't eat a dead chicken!" With a proper tone of voice

and certain facial expression, this remark can be made at a dinner table to cause everybody present to refrain from eating chicken.

Flouting of Logic

Related to the conceited ignorance which dismisses the specialist's distinctions as verbal refinements, as mere quibbles, is the audacious challenge to the expert to prove things that, in the nature of the case, simply cannot be proved. A flagrant example is the repeated offer of opponents of vaccination to pay a thousand dollars or a thousand pounds for any evidence that vaccination has ever saved a single person from smallpox. This challenge, addressed to "any doctor present" and thrown out to a highly emotionalized audience, never brings forth the evidence, but always enthusiastic applause. The evidence demanded is, in the nature of things, unobtainable, yet complacent ignorance continues to demand it, and continues to exploit the failure of the doctors to produce it as a means of discrediting both the specific practice, namely vaccination, and the whole scientific foundation of medicine.

Individual Differences

It is a well established generalization about living things that no two individuals are exactly alike. Whether we are concerned with outward

appearance and physical measurements, or with mental capacities and physiological reactions, individual variation may be considered a fact of reality. A given noise, for example, will be heard by most people in a given region, but a few will not perceive it; on the other hand a few will hear a sound that most of those present will not perceive. A whole village is exposed to typhoid fever infection by a faulty water supply, yet not all will become sick. Of those who do become sick, some will recover easily, some will have a severe illness, and some will die. In any situation that affects numbers of people, it is impossible to tell in detail either how each individual will respond, or why the responses vary as they do. If all the inhabitants in a village come in contact with a smallpox patient it is probable that some of them will escape infection regardless of whether they had been vaccinated or not, regardless of whether they go to church regularly or not—or to which church. It is therefore quite true to say that in the case of any particular person a lifetime of freedom from smallpox cannot be definitely ascribed to a particular event, such as vaccination. Nevertheless we may say confidently that the significance of such an event can be fairly measured in a statistical sense and only by statistical methods. If we find, for example, that smallpox strikes indifferently republicans and democrats, the faithful and the infidels,

the vaccinated and the unvaccinated, we may say that political or religious affiliations and vaccination are not factors in protection against smallpox, and that they are not factors in susceptibility to smallpox. If we find, however, that democrats, for example, or Jews, or left-handed persons, or vaccinated persons consistently show a higher or lower percentage of smallpox, than other groups in the population, we may be sure that we have a factor that is related to protection or to susceptibility.

It so happens that wherever reliable records are to be had for large masses of people, there is a consistent preponderance of smallpox cases among the unvaccinated. While it remains true that we cannot in any particular instance say that this person was saved from smallpox by the fact of his vaccination, we can say that thousands, yes millions of people, have been so protected. Yet that phase of our comprehensive ignorance which remains complacent in its own conceit, will refuse to accept the logic of the statistician, and will insist upon being shown the value of vaccination "in a single instance." Here again the Republic needs no scientists.

Credulity versus Knowledge

Credulity is the vice that makes tyranny and autocracy possible, because it prevents the growth

and diffusion of knowledge. An autocratic organization of human relations depends in part on the facility with which masses of people can be made to believe. It can maintain itself indefinitely in the midst of misery and ignorance and superstition, so long as people make a virtue of unquestioning faith. Those in control need not be superstitious, they need not be ignorant, they need not believe in the divine origin of Kings as they ask the masses to believe. They need instead to discriminate between knowledge which is useful for the purposes of the masters, and popular beliefs—which are also useful for the purposes of the masters.

Under such circumstances knowledge or science cannot expand. Investigation, the search for new ideas, new facts, new understanding is penalized. The man who makes even a casual observation is afraid to speak of it, since it is out of harmony with prevailing beliefs and doctrines. In an autocratic scheme of life doubters must always be discredited and discouraged.

Democratic Credulity

In a democratic community, however, credulity is not so essential. We do not have to believe that the mayor or the sheriff is infallible. We do not have to believe what any authority tells us. Indeed, we pride ourselves on our liberty,

which leaves us free to believe or not whatever idea comes along, entirely, as we suppose, on its merits.

As we throw off the enforced beliefs, science expands, producing new marvels of invention, most ingenious devices, startling innovations in every field. It is inherent in certain results of our scientific advance, namely the means of communication and conveyance, that new facts, new ideas, new devices shall be made quickly available to all. This does not mean that we all become quickly possessed of new principles, new discoveries worked out by the scientists. That would be impossible. It means only that *information about* such discoveries is broadcast; we get only the end product, or perhaps only a new word that makes us pucker our foreheads or feel the thrill of living in such a wonderful age.

Having questioned authority and so opened the road for investigation, we have taken on a new credulity. A new magic and a new superstition have arisen from the very impressiveness of scientific achievements.

Nothing that the magician or the mystery monger calls upon people to believe is inherently more marvelous or incredible than the discoveries of the scientist and their practical applications in what the untutored man sees around him every day. Communications from the dead are no harder to understand than the music and lectures

that come through space and pour out of the radio. The making of gold out of lead, or something out of nothing, is no harder to believe than the making of perfumes and drugs out of kitchen refuse, or out of the muck from the gas house. If invisible, odorless and tasteless gases—that is, something not apparent to our senses—can indeed diffuse and deal death, why may we not believe that equally intangible somethings—like absent thoughts—can cure our troubles? If the law compels us to believe that a few drops from the blood of an infected horse will prevent or cure diphtheria, it is at least as reasonable to believe that skillful luxation of the vertebrae will cure syphilis—just as reasonable, that is, to those who do not know what is involved.

Credulity of Ignorance

If these examples of credulity amuse you, it is because of your satisfaction with your superior knowledge. If you understand the action of fire, you laugh at people who invest money in a scheme to recondition ashes for a second and a third use. If you are familiar with the anatomical relationship of the dorsal nerves and spaces between the vertebrae, you laugh at the ignorant people who visit chiropractors or bone setters for treating infections. If you know something of the structure and functions of the brain, you laugh at the

willing victims of phrenology. You realize that the exploitation of credulity depends upon ignorance; but we need to recognize further that ignorance is both special and relative, like its opposite, knowledge or information. One may be very knowing, but nobody knows everything; and what one knows is always a specific body of facts or principles.

The most generalized ignorance to be found in civilized communities today is illiteracy. We have glorified the art of reading to the point where even those who read with considerable facility are yet subject to a certain glamour that attaches to the printed page a wholly disproportionate value. To those who cannot read at all, there is magic in the printed page. This may be a relic from the time when printing was confined to words of great moment (to the sacred words in fact) and readers were few. This faith in the printed word is easily exploited. A leaflet distributed by a large insurance company shows an old-fashioned street-corner faker offering a bottle of some cure-all. He is represented as saying: "This will surely cure you! But do not take my word for it. Don't take anybody's word for it. Read it for yourself, right here on the label!"

This faith in the printed word has enabled its exploiters to accumulate vast fortunes in the patent medicine business and in wild-cat stock

schemes. Many of us are above yielding to such gross appeals to ignorance. Yet precisely the same kind of credulity is to be found among those who consider themselves well educated.

Credulity of the Learned

The more we learn, the better prepared we are to appreciate the new marvels of science. If we know a little history, we are afraid to be classed with those who obstructed the progress of the race by frustrating genius and burning heretics. We remember how the conservatives of the past said "Impossible!" and how the impossible has become commonplace. Moreover, the more we know, the more we are supposed by our neighbors to know, the less do we like to admit our ignorance. Thus we, who consider ourselves educated members of the community, are rendered susceptible to a special type of exploitation.

Here is an extract from a circular letter addressed to the doctors of medicine, one of the most learned of professions. "Dear Doctor," it begins,

"The discovery of radio-activity has revolutionized science. The revelations of the electron have compelled a new way of thinking about the universe. Have you followed the work of such scientists as Steinmetz, Luckiesh, Michelson, and Millikan in America and Thomson, Ruther-

ford, and Soddy in England? If you have, you already realize this.

"We know that heat and light and sound are only three letters in the alphabet of energy. M. Luckiesh, Director of Applied Science with the General Electric Company says:

"If a normal spectrum of the entire range of wave-lengths of radiant energy could be produced and the portion of it due to visible radiation—light—were one foot long, the entire spectrum would be SEVERAL MILLION MILES IN LENGTH."

"As we learn more letters in the alphabet of energy our mastery increases by leaps and bounds and already is giving us a hitherto undreamed-of control of the world in which we live.

"This control applies to medicines as elsewhere, due largely to the work of a man whom Sir James Barr, M.D., Ex-President of the British Medical Association, links with Sir Almroth Wright as one of the two great medical geniuses of the last fifty years. Bitterly attacked and maligned, like Jenner and Lister and Semmelweis, Albert Abrams "being dead, yet speaketh," and the leaders of medical thought around the world are listening.

"A group of prominent English practitioners, aided by well-known physicists have been studying his work for several years past and testing out his methods of diagnosis and treatment. They have just made their findings public in a volume entitled

Abrams: Methods Of Diagnosis
And Treatment

a book which has created a sensation in England, where several printings have been sold out in a few weeks."

You see what this says. Certain famous scientists have made great discoveries.

They are important discoveries. They have been acclaimed by means of awards and prizes and medals and decorations.

They are far-reaching discoveries. They may affect our daily lives in many ways, as in industry, communication, transportation, health.

And they have to do with something that most of us do not understand, not even the doctors—namely, Matter and Electrons!

There must be something of great value in a system, or a machine, that makes use of these great, important new discoveries—and electrons. I don't know just what it is, but I honestly believe that it is important. I don't understand it. Even if I were a doctor (or especially if I were a doctor) I couldn't understand it. And why?

Well, because, for one thing, it isn't so.

Scientific Words—Unscientific Foundations

One of the great scientists mentioned in this letter, a leader in the pursuit of electrons, a winner of the Nobel Prize, is Dr. Robert A Millikan,

Director of the Norman Bridge Research Laboratory in Physics, at Pasadena.

Dr. Millikan claims to know nothing of medicine. He examined the machine and the system, as an expert on electrons and electricity. This is what he says of the Electrics of this "System":

"As you know, I have spent the greater part of a day listening to the description of doctors who use the so-called electronic methods of Abrams and in a very careful examination of the instruments and technique of the method itself. As you will remember, I made a portion of this examination of the Abrams method when I was alone with the doctors who were practicing it, and another portion when you yourself were present and took part with me in the examination.

"I scarcely need to say to you or to any other intelligent man who has examined the method that I do not consider that it rests upon any sort of a scientific foundation whatever. Indeed, from the standpoint of physics the claims set up by Abrams and his followers are the height of absurdity. They talk about finding the vibration frequency or vibration rate of each particular kind of disease, and they then claim that they can destroy the micro-organism which has that vibration rate by imposing upon it from without its own frequency or vibration rate. Yet when they are making a diagnosis they attempt to find the natural frequency of the disease by inserting more or less electrical resistance into a circuit which cannot oscillate at all and therefore has no vibration frequency, and if it could oscillate the period

would not be changed at all by inserting more or less resistance. In other words, the setting of the dials of the resistance box upon different buttons cannot possibly make it respond to different frequencies, since the electrical system used is in the first place one which cannot oscillate any way, and in the second place if it could oscillate it would oscillate in the same period whatever button of the resistance box the dial was turned to; so that the claim that a diagnosis can be made by turning the dial to different buttons and thus tuning in to different frequencies simply indicated complete ignorance of the fundamental laws of physics by the one who makes it."

A Pathologist's Findings

Dr. W. A. Price of Cleveland, who does not pretend to know much about electrons, but who has spent many years in the study of sick conditions in human beings and other animals, also studied the machine. This is what he writes:

"I told the demonstrator that I would send him this detailed written report, but before doing so I wanted to go over with him in detail, while all these witnesses were present, many things that had occurred. I showed him, for example, the specimen of blood which consisted of water-color paint and argyrol, and reminded him of his reading, which indicated that this patient had streptococci in the ears, tonsils, heart, colon, and gall-bladder; 30 ohms of congenital syphilis, affecting the nerves, brain, bones and joints, and digestive

tract, and $7/25$ ohms of cancer, located in the left breast and uterus; also, how the specimen of rabbit's tissue, and, later, blood from this rabbit, which he was analysing, was from a rabbit recently examined post-mortem, which had died of tuberculosis of the lung, the culture of which we had inoculated, and now his statement was very positive that there was no evidence of tuberculosis indicated from this specimen; how he had given three different readings on the same patient, all very different; how his reading of the blood of the patient with syphilis indicated that that patient did not have the disease and that practically all the readings of other samples in the three sessions had shown syphilis; how, out of six trials that he had made to tell whether the specimen was in or out of the dynamizer, he had been in error five times, when, according to the law of chance, he should have been right half the time; and, finally, how he had worked for hours with his machine with his circuit interrupted by the removal of the core from the wire and placing wax therein, with conditions which he stated to be particularly satisfactory so far as the working of his instruments was concerned. I also showed him the insulating wax in the wire, which is so splendidly dielectric that it is used for insulation for high potentials. When he suggested that possibly this was a good carrier, I made a test of this by a very sensitive galvanometer with a high voltage; which would have completely ruined the instrument had there been good capacity for conduction. Indeed, this instrument would show a millionth of an ampere of current, and there was not the slightest deflection; in other words, it had a resistance

approximately equal to that of a telegraph wire reaching from the earth to the moon and back.

"He assured me that he recognized that he had been mistaken, but that he had acted in good faith and never thought to make such tests for himself. It was mutually agreed that I would not publish his name but that he would write to the proper officers of his local society and explain that he had been mistaken, and that he would discontinue its use and use his efforts to have the practice discontinued by others in his community. He stated that I was privileged to publish this report without his name.

"The seriousness of this matter in the interest of humanity cannot be estimated. I have been told of a case of an unmarried woman who committed suicide after being told by this method of diagnosis that she had syphilis, and of a practitioner, who is probably only one of a great many, who is treating up to and exceeding 100 patients a day on the basis of \$6 an hour, or \$3 for half-hour treatments. The demonstrator told of an operator who had made more than 7,000 blood diagnoses, a large part of the patients receiving treatments by him or by others, and that the average cost per patient for treatments would be about \$100. We were advised by the subject¹ that a customary charge for the time spent reading a patient's blood was from \$10 to \$15 and that it took from ten to fifteen minutes, or a dollar a minute. He stated frankly that he was personally not interested in whether the instrument

¹ The subject is a presumably healthy person who serves as part of the examining equipment. Ed.

was efficient or not; that he was concerned and interested in the money that he got for acting as a subject, and that he had been serving as a subject for about five years. He cited cases where he thought cures had been made."

Skepticism an Obstacle to Progress

The achievements of science have developed a new skepticism. In spite of our practical control of scientific appliances most of us really do not understand what is happening. We cannot deny our senses; but we cannot explain what we see. Our self-respect is wounded by the assurance and self-confidence of the scientist. We therefore oppose his progress with our own ignorant prejudices.

The United States Department of Agriculture, in cooperation with State agencies and county organizations has developed an elaborate and effective program for the elimination of tubercular cows from the dairy herds of the country. In some regions the work has proceeded to a very satisfactory stage; in others, militant ignorance obstructs it. "Do you know what tuberculin testing does to the cow? Do you know what it does to the milk?" Delivered with strident voice and hysterical manner, these unanswerable questions make thousands shudder. "And you feed milk from such cows to your child!"

Certainly tuberculin testing is neither fool-proof nor 100 per cent reliable. It is, however,

an effective means for identifying the tubercular cattle on a large scale, and is a useful aid in reducing tuberculosis among cows. Since cattle represent substantial money costs there is often a commercial motive in opposing the use of tuberculin tests. It is possible also that the application of the test on a large scale opens a market for supplies and materials and opportunity for corrupt practice. Yet the merits of the tuberculin testing as a physiological procedure, or the safety of the practice, must be determined by strictly scientific methods and not by asking people if they like the idea, if it appeals to their common sense, or to their business sense. The value or safety of tuberculin testing can certainly not be ascertained by a popular vote.

Pride of Ignorance

It is easy enough to arouse suspicion of those whom we do not understand. Such suspicion is of course not admirable and must be cloaked in respectable guise; but this, too, is easy enough. The doctor, for example, writes his prescription in Latin; what is that but a scheme to confuse the layman, to enable the druggist to exact an exorbitant price for some cheap drugs, or merely to impress us ignorant people? Democracy gives us the right to know what the diplomats are doing, and we ought to have our prescriptions

written for us so that we may be able to read them ourselves—even to compound them if we wish.

There is no virtue in a Latin name, except the fact that Latin is a dead language! In a living tongue changes in meaning constantly emerge, and there exist variations of meaning in local usage. The common names for common plants illustrate clearly enough what the difficulties are. For most people, a maple is a maple, an oak is an oak, just as pigs are pigs. But to one who knows maples or oaks, one of these names is hardly more helpful than the name "tree" where something specific is meant. Not only are there many different species in each group, without distinctive common names, but a common name means in one locality an entirely different group of plants from what it designates in another. The same is true for chemical compounds or preparations, for most of which there are no common names at all.

If it is true that a physician may hide his ignorance behind a formidable Latin word which merely names a substance or a symptom, it is also true that without a uniform terminology it would be impossible for the profession to exchange experiences and to insure the use of materials or methods as intended. A fixed name for each specific substance used is as important as a definite meaning for inch, or dollar, or degree Fah-

renheit. The fact that these units of measurement are known by familiar names does not make their essence or principle any more intelligible to the ignorant person.

Skepticism Defeats Its Purpose

A person who has been injured or deceived by believing too readily the words of a stranger is likely to react by becoming too suspicious of strangers. If we believe everything, we are sure to be imposed upon, whether it be in religion or in politics, in business or in social dealings. It is wise to be cautious, to examine everything carefully. The scientist has himself encouraged a form of skepticism which he likes to consider philosophical; and in this he has of course worked in harmony with the democratic tendencies of the time. But whereas the scientist demands of every new idea that it justify itself through facts and logic, the skeptical layman is content to disbelieve, without taking the responsibility to discriminate. This means the exercise of the right to believe what pleases us to believe. The ease with which new ideas are ridiculed—we have merely to emphasize their departure from the accepted and familiar—brings about a disparagement and discrediting of science and scientific pursuits. This kind of skepticism which is merely a crude hostility to the new and strange, defeats

the legitimate purposes of reasonable caution by encouraging irresponsible ignorance.

A type of advertising that has come to be quite common in certain parts of the country will show how this ignorant sophistication, which suspects only because it does not understand, can be exploited. The essential part of this advertising consists of preparing its prospect's state of mind by enumerating the failures of science. The doctors have no specific remedy for rheumatism. In certain types of hemorrhages the doctor is perfectly helpless. For certain infections the doctor can do nothing but make the patient more comfortable. Dozens of extracts may be taken from medical text books describing situations for which medical science has found no remedy. One little book enumerates "one hundred and one reasons" in the form of extracts, all leading to the conclusion—*therefore come to us!* That is to say, since the experts, the scientists, acknowledge a vast number of problems that they have not solved, this advertising appeals to your common sense to rely upon persons who do not even know enough to differentiate between the known and the unknown.

Progress

In an autocratic society virtue resides in the established order. There is no expectation that the humble individual will progress to high social

rank or that the peasant will some day become president. There is no expectation that society as a whole will advance to a happier state of affairs for all the individuals. The common mind is not cultivated to anticipate important changes of any kind; progress is not a catchword. Since modern democracy is itself the expression of a revolt that justifies itself as a forward step, a means of enhancing the general welfare, it must, in general, accept progress as a permanent characteristic of social life. The public therefore approves of "progress", although it may not be able to distinguish what is progressive from what is merely different. A cultist appears progressive when he may be only arrogant and presumptuous in his ignorance, or actually reactionary in the sense of resorting to practices long since abandoned as worthless. Every generation supplies a new crowd of victims for some form of "Mesmerism", and a new crowd of witnesses with their self-deceptions and testimonials. An old panacea is driven from the market by a governmental "fraud order", only to emerge from a new habitation under a new name. The readiness with which masses of people follow the quack may be indicative of a sort of intellectual *sans-culottism*, for notwithstanding the secret aspirations of masses to attain to respectability and exclusiveness, our democracy seems to attach a special virtue to any cult that disparages the reputable.

Opposition to Progress

So long as the new is offered in terms of democratic revolt, it may be made acceptable to large numbers. Since, however, the large masses of people are not trained to an appreciation of the methods by which science makes advances, genuine progress that rests on scientific research is very easily made to appear unreliable or dangerous. Again and again opposition to medical science appeals to this public ignorance by pointing out that through the centuries fashions in medical practice have constantly changed.

There was a time when the doctor speculated in the "humors" the bodily fluids were supposed to determine personal characteristics and maintained health through their proper balance and interaction.

Centuries later the physician sought the sign of nature's purposes in the physical characteristics of plants, animals and minerals. The doctrine of signatures, radically different from the doctrine of humors, held sway for centuries and still colors at least the language of modern medicine. This doctrine is very simple and can be made to appeal to "common sense". It is based on the assumptions that God, or Nature, provided for each of the human ailments a suitable remedy, and placed upon this remedy a sign whereby man could recognize its purpose. The kidney-shaped leaf

of a certain plant is a sign that the juice of this plant is a remedy for kidney complaint. The hairiness of the bear is a sign that the grease of this animal is a remedy for baldness. The wrinkled kernel of the walnut bears the obvious sign of its suitability for curing brain troubles. Many gallons of celery compound serve the faithful in this country every year as a nerve tonic: and the only connection between celery and the needs of nerves is found in the "nerves" that show when the celery stalk is broken. Absurd as these notions are, they did actually guide the doctors for many generations; even today the doctor speaks of what he intends to prescribe as being "indicated" by the symptoms—that is to say, the sign or symptoms *point to* something or other.

With the passing of time, blood-letting came to the front as a means for relieving suffering, sulphur and molasses had their day. In all of these changes the ignorant find irrefutable arguments for the probable futility of present-day medical practice. It is almost impossible to answer to the satisfaction of the untrained mind the question "How can you tell that serums and vaccines will not be rejected as useless tomorrow?" There is here displayed the mental attitude of one who refuses to make use of the aeroplane, not because he can find any specific defect in the machine, but because the models of 1926 are so

different from those of 1916—and the latest may also be superseded. Instead of thinking of the progressive improvements, one may think of the defects revealed by each improvement.

We Live by Theory

The fact that man used to drive out evil spirits by means of hideous noises, but now neutralizes bacterial poisons by means of antitoxins, may signify no more than a change in fashions. It does, however, mean a great deal more. Throughout the ages man has attempted to control his material environment and he has been obliged at each stage to base his technique upon some *theory*. The practical person prides himself on his freedom from such tenuous cob-webs; his feet are planted on solid ground. Nevertheless, every step he takes rests upon certain assumptions, whether he is capable of formulating them or not. Where these assumptions are held in common by many people we speak of them as common sense. Every improvement in technique, however, comes from modifying these assumptions. It is common sense to drive out evil spirits, where common sense assumes that it is the evil spirits which cause illness. It is common sense to use liverwort for liver trouble where common sense assumes that the shape of the leaf is a sign of its use.

Through all the ages there have been changing

fashions in common sense, but only within the past century and a half has there been any systematic attempt on the part of large numbers of people to check the validity, the reliability of what everybody knows without questioning. And it is this which makes modern science so much more powerful than any common sense of the past, and which at the same time makes it subject to suspicion and hostility. We are in a position today to know with a measurable degree of certainty that an antitoxin is reliable for certain purposes, even while we admit that any day may bring forth new discoveries that shall force us to abandon this antitoxin. By means of experiment we are enabled to say that a given device is sixty or eighty or ninety per cent effective, or that it involves a risk in two or ten or one-hundredth of one per cent of cases. Scientific medicine differs from all the wisdom of the past in just this one point, that it rests upon systematic research and not only supersedes earlier usages, but considers itself merely a link in a long chain of progressive advances, likely in time to be itself superseded. Where our practice rests upon lucky guesses or un-confirmed assumptions the change in fashion carries with it a disparagement of what is superseded. Where our practice rests upon scientific research we may confidently use that which will probably be superseded, because it is for the time being the best to be had.

A Little Knowledge

Where the masses are kept in total ignorance and policies are determined by the few who know, there is comparative safety for all, even though famine and pestilence rage, even though the death rate be such as to keep the average length of life at twenty-four or twenty-five years. Where democracy calls for a diffusion of learning, we are soon confronted with the appalling fact that a little knowledge is a dangerous thing.

Many years ago a man in the molasses business, who had occasion frequently to send samples of proffered wares to a laboratory to be tested for possible adulteration with glucose, discovered that he could save this expense by the use of a fifty cent set of Fehling Solution. This man suffered from diabetes and his doctor had instructed him in the periodic testing of his own urine with Fehling Solution; and being an intelligent person, he had asked questions and found that the test showed the presence of "glucose" in urine. Putting two and two together he realized that he could test molasses himself and save the chemist's fee. He found, much to his astonishment, that *every* sample submitted over a period of weeks contained "glucose". Finally he came upon a sample which he knew to be unadulterated; but again his test showed glucose. Upon this he brought several samples to the chemist from

whom he learned that the every-day word "glucose" meant one thing to the dealer in molasses and another thing to his physician: all molasses contains the kind of glucose that Fehling Solution reveals. By making use of his too little knowledge the dealer actually lost business for several months; although he did save the chemist's fee. This little knowledge was reliable enough as far as it went; but it did not go far enough.

Now when we are confronted with the fact that a little knowledge is indeed a dangerous thing we have a choice of two practical alternatives. We may say, as some do, Therefore, people should have no knowledge whatever; or we may say, Therefore, people ought to have more than a mere little. It is probable, however, that neither of these alternatives can be universally satisfactory. We cannot insulate people completely against this penetrating something that we call knowledge; neither can we make sure in all cases of supplying the needed supplement to the dangerous little.

Reliance Upon Authority

Everybody does indeed realize as he becomes older and somewhat wiser that there are some things which he does not know. The result of this ought to be a universal disposition to consult authorities. The difficulty comes not from our

unwillingness to submit to authorities, but first, from our inability to discriminate between authorities; and second from the failure of the authorities themselves to recognize their own limitations. The typical case of the foolish resort to authority is that of the poor widow in Indiana who went to the minister for advice on investing what remained of her late husband's estate. The minister is an honest person, he is more intelligent than most of the people around him, he is better informed on things in general than his parishioners. What then is more logical than an appeal to him when counsel is needed? He advised to the best of his ability, but the advice proved unsound.

We are all flattered by being consulted. A great deal of pompous nonsense seems to be uttered in perfectly good faith. There is no necessary connection between the *confidence* with which an authority on merchandising expresses opinions on educational or political matters and the *soundness* of his judgment on specialties beyond his own field. Moreover, there is a real danger in too ready an acceptance of the utterances of authority even where the authority is quite sound and trustworthy. Public welfare requires that, in each situation, the best knowledge, the best technical judgment be made available. Public welfare requires also that the interests of the

masses be conserved, and for this reason democracy demands freedom from autocratic control even by experts, however benevolent and wise. Democracy would rather make mistakes while attempting to solve its problems than be dependent upon the irresponsible few who can solve problems without making mistakes.

Democracy Needs Science

In emphasizing the obstacles that democracy presents to the progress of science we are by no means making out a case against democracy; after all, science is not an end in itself, nor is democracy an end in itself. It could as easily be shown that science is subjected to such abuses under autocracy that its humanitarian possibilities are completely overlooked or destroyed. The reliability of science or its worth to mankind cannot be ascertained from a superficial consideration of past applications or misapplications. The abstraction "science" and its disciples, the scientists, are frequently attacked, for example, because systematic knowledge and research have been so thoroughly applied to the destructive processes of war. It is as foolish, however, to blame science for the uses to which it is put as it would be to blame the automobile manufacturer for the fact that some of his products have been

used by brigands to escape from the scenes of their crimes. As an instrument, science is neither moral nor immoral.

The concern of democracy is to make more and more use of science, to make itself more and more master of this instrument. The republic has great need of science, and will make increasing use of it only as the diffusion of education overcomes superstition, and as the diffusion of culture makes it possible for the scientist to serve the public interest rather than any special or partial interests.

It may be that our education has been too one-sided in that it narrowed the specialist and left his thinking unrelated to the common needs, while it left those of us who are not expert in anything without appreciation of the value of expertness and without confidence in the integrity of the men and women we cannot understand. The critical attitude involved in much of the hostility to specialists is a precious asset in our common thinking; it is essential to the progress of science as well as to the security of the public. Without losing the benefits of criticism we should be able to get the cooperation and confidence of the public for those whose special knowledge and skill are drawn from the experience of the whole race, and whose activities can be made of such great service to mankind.

We are already using science as it is applied in the improvement of communication and transpor-

tation, of lighting and heating, of agriculture and bridge-building. No fairly informed person to-day claims as a right the exercise of private judgment on thousands of technical questions in these various fields. Yet many a person who consults experts on investments or fertilizers, on insurance or strength of material, considers himself competent to criticize public health practice or medical theories. This is in part at least due to the fact that traditionally the healing arts have been closely associated with religious practices, and we are living in an age of protest against domination by religious authority. It is true that all the practical arts have been gradually differentiated from the practices of the priest; it is apparently only a question of degree. Thousands of people who would think it absurd to consult the church on technical details about planting and harvesting, about road-building or well-digging, nevertheless regularly consult the church on technical details about treating diphtheria or preventing typhoid fever.

It is likely that much of the prevailing sickness is closely related to our spiritual conflicts and difficulties; and many people feel the irrelevance of ordinary "medical" measures in such disorders. It would nevertheless seem to be good sense to encourage the methods that have revolutionized our industry and agriculture and that have so vastly increased our productiveness and our mas-

tery of materials. It would seem to be good sense to recognize the advantages of scientific methods in dealing with new problems, even where we are aware of the limitations of the scientific knowledge already attained.

Whatever may have been true in 1794, we must recognize that today the Republic can thrive only as it makes intelligent use of the Scientist.

THE INDIVIDUAL,
A PRODUCT OF INHERITANCE
AND ENVIRONMENT

Charles R. Stockard, M.D., Ph.D.

CHAPTER II

THE INDIVIDUAL, A PRODUCT OF INHERITANCE AND ENVIRONMENT

What is meant by physical inheritance? The usual thought about this question is that physical inheritance is the resemblance of children to their parents. In a general sense this is correct. The answer might also be given in the common phrase that "like begets like." If, however, we look more closely it will be found that such definitions are not completely true. The child may resemble the parents in certain features but it is not exactly the image of either one of them, nor is it an exact combination of both. A child may exhibit certain characters and features that are not present in either parent and it may lack certain features that are present in both parents. Strictly speaking, like does not fully beget like. How do these differences come about? Are they not also inherited? Inheritance is probably not merely the resemblance of the child to the parents, but also the resemblance of the child to a great number of ancestral combinations. The child in some way is an expression of the history of its race, and yet

even such a particular definition as this is not entirely correct because the individual child might actually present some peculiar features which are possibly new or extremely rare for the race.

It has often been observed that on crossing two animals the offspring do not strictly resemble either parent in certain characters but present a blend of the two parental characters. This is also shown in the mulattoes, from crosses between white and black races of men. Again, in crossing two animals, it sometimes happens that the offspring resemble very closely one of the parents in particular characters and are entirely unlike the other parent—for example, when a normal person is mated with a non-pigmented albino all of the children are normally pigmented and none are albinos. This has been called incomplete inheritance. Again, the offspring from such a combination may differ in certain characters from both parents, and may revert in appearance to the pattern of more remote ancestors. This phenomenon has been termed “reversion” or atavism. An example is the banded pattern or striped legs occasionally seen in colts and thought to be a reversion to the ancestral horse pattern.

The Continuity of Life

Such phenomena as the above have been well known for a very long time and have given rise

to much speculation and theoretical consideration of how inheritance actually works. The last half of the nineteenth century was particularly fruitful in speculation and theory regarding the physical basis or mechanism of inheritance. One of the most prominent biologists then taking part in these discussions was August Weismann, the originator of the idea of *the continuity of the germ-*

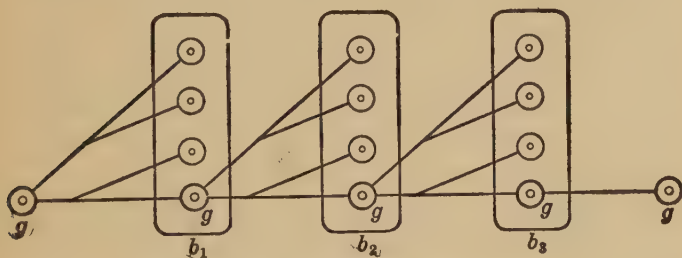


FIG. I. THE IDEA OF THE GERM PLASM

When a fertilized egg, *g*, develops into a new individual, *b*, part of the protoplasm becomes the body, or *soma*, and part remains germ, *within the body*, where it is nurtured. The germ is not a product of the body in any sense. Each body, *b*₁, *b*₂, *b*₃, is a branch, or development, of the germ, but the stream of germ material is continuous. The nature of the germ determines the kind of individuals or persons that will develop; the body does not influence the germ.*

plasm. According to his conception the reproductive stuff or germ-plasm was set aside and continuously passed on from generation to generation: while the individual developed, spent its

*From Elementary Biology, by Benjamin C. Gruenberg; Ginn & Co.

life and died, the germ-plasm was continued and passed on in the offspring.¹ In a general sense of course such a conception is essentially correct, but it might better be expressed as the continuity of living stuff rather than of germ-plasm. All offspring are not necessarily derived from the definitely localized germ-plasm but, as in the case of many plants, a new individual may arise from a cutting or shoot, or from buds or even leaves in certain plants. The individual plants so derived are perfectly capable of complete development and of actually giving rise to new germ-cells of their own. In all cases, however, a living individual is invariably derived from some previously living parent. There is no such thing, so far as we know today, as spontaneous generation, and the truth is that every individual has been derived from some parent individual and that parent was likewise so derived, until the life stream of which we may be called the present

¹ This idea of the continuity of the germ plasm was derived by Weismann from the fact of "immortality" as seen in the lowest organisms. Among one-celled animals, for example, the individual may be destroyed in many different ways, but never dies a "natural" death. After attaining full growth the individual divides into two similar parts, and each of these continues to live and grow. The first individual no longer exists as such, but its substance continues living in the two daughter-cells. This process is repeated, and so on, generation after generation. In this sense, then, the living matter is deathless, although the existence of the individual is definitely limited, beginning in one cell-division and ending in another cell-division: the plasma of the species continues through the ages. See Fig. 5, page 143.

representatives must reach back for thousands of years towards the beginning of life on this world.

An understanding of inheritance fully depends upon this idea of the continuity of living stuff. Living stuff at the present time is wonderfully diversified and is divided into a huge number of specific kinds: the animal species we know, such as humans, dogs, birds, etc., and the plant species, such as daisies, oaks, and mosses. The origin of this great diversity is the fundamental problem of evolution, and it is intimately associated with our present problem of inheritance.

Mendel's Laws

Various questions concerning these grand problems were occupying the minds of biologists at the end of the last century, and it so happened that just at that time, in the year 1900, three botanists simultaneously rediscovered important laws of discontinuous inheritance of dominant and recessive characters.

Let us consider some examples. When a tall variety of a certain plant is crossed with a short variety of the same plant, all of the first generation of plants (F_1)² from this cross are tall, like one parent: thus tallness is the *dominant* charac-

² This symbol F_1 represents the first filial generation, or the immediate offspring of the parents with which the study or experiment starts. F_2 is read second filial generation, and so on.

ter and shortness is *recessive*. When these tall F_1 plants, derived from such a cross, are bred among themselves they give rise to two kinds of F_2 plants in the definite proportion of three tall plants to one short one. The short plant so derived is "pure" and breeds pure with its own kind from then on. One third of the F_2 tall plants are also pure, while two-thirds of them are mixed like the F_1 parent from which they sprang, and these, when bred together, will again give offspring which break up into the three-to-one or "Mendelian ratio".

The botanists Hugo de Vries, G. Correns, and E. Tschermak, found that this peculiar mode of inheritance had been described in 1865 by an Austrian monk and abbot of Brunn—Gregor Mendel. His valuable results had not been appreciated when published and had actually been lost to science for thirty-five years. A few years after these laws were known for plants, the great English geneticist, William Bateson, whose recent death is mourned by Science, found that these laws also applied to the inheritance of certain characters in animals.

A great number of botanists and zoologists then became actively interested in the new possibilities of the experimental study and analysis of inheritance. It might be said with full regard for the value of the work done by earlier investigators

that the modern experimental study of inheritance really dates from the year 1900, and the accomplishments which have been attained are almost entirely due to the realization and appreciation of the significance of Mendel's laws of inheritance.

Like many other important deductions and generalizations in science, these so-called laws are not completely true as originally stated in their bold, general way. Nevertheless, it has been on the basis of these laws, and actually through the fact that they are not universally true, that finer and more far-reaching discoveries on the nature of the mechanism of inheritance have been made possible.

Chromosomes in Cell Division

Very soon after it became known that certain characters in animals and plants alternated in their appearance and could be shifted back and forth in inheritance, investigators began to wonder by what living mechanism in the cell such shifting and redistribution could be brought about. A number of investigators had before this come to believe that certain bodies, called *chromosomes* and found in the nucleus of each cell, were actually the carriers of the hereditary qualities. These chromosomes had been found to exist in definite numbers for each species, and to be accu-

ately divided and sorted out to the two daughter-cells during the process of cell-division or cell reproduction. The division of each chromosome and the precise allotment of the similar halves to the two daughter-cells seemed a most significant phenomenon.

Chromosomes in Reproduction

It was also known that when the egg and the sperm, or male germ-cell, matured, a peculiar cell division and assortment of the chromosomes took place by which their number in the cell became reduced to half. After this reduction division fertilization takes place, in which the egg with one-half the original chromosomal number combines with the male sperm cell, also with one-half the number, and thus the original number of chromosomes is restored.

Another valuable observation was then made, showing that the several chromosomes of the cell nucleus are not all exactly alike but differ from one another in some cases in size and shape. Further, the chromosomes of various sizes and shapes occur in pairs. Thus, the chromosomes in the cell are actually a number of similar *pairs*. One member of each pair is presumed to be derived from the mother and the other member from the father, at the time of union of the male element or sperm cell with the egg cell.

Chromosomes in Inheritance

A young zoological student, William Sutton, now originated the idea that the sorting and shifting of the chromosomes in cell division and the reduction of the number of chromosomes in the maturation of the egg and sperm, with the re-establishment of the species number at fertilization, was actually the mechanism through which the characters in alternate inheritance were shifted so as to give the Mendelian ratios. This important deduction of young Sutton attracted wide attention and there was very soon a general acceptance of his idea of the connection between the sorting of the chromosomes during the reduction divisions and the shuffling or alternating of characters in Mendelism.

Chromosomes and Sex Determination

Only a year or so after this another important discovery was recorded. A peculiar difference in the number and appearance of the chromosomes in the two sexes of the same species was recognized by Clarence E. McClung, then at the University of Kansas, and it was suggested that this chromosomal difference was actually the thing which determined the sex of the individual at the time of fertilization. This significant difference in the chromosomes of the sexes was beautifully

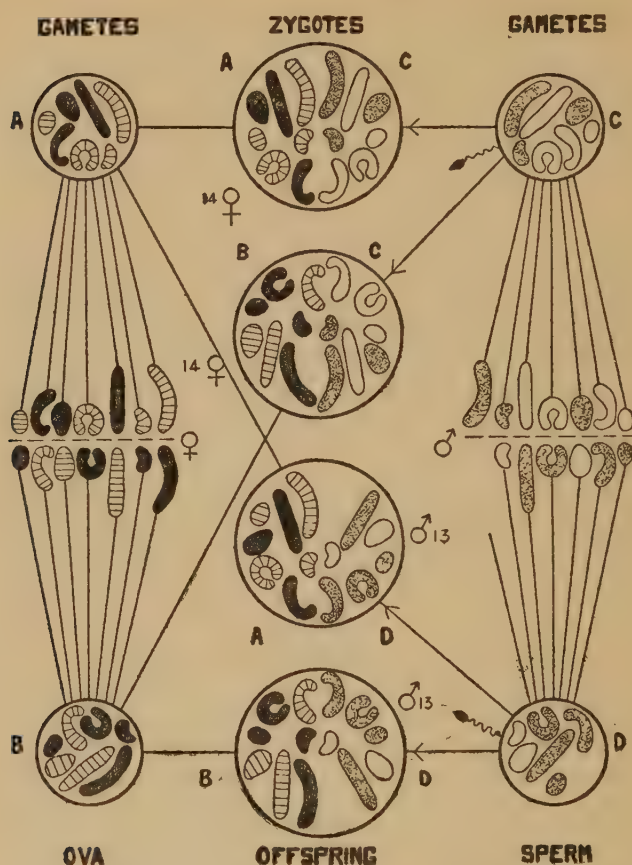


FIG. II. CHROMOSOMES IN INHERITANCE AND IN SEX DETERMINATION

The number of chromosomes is constant in the cells of a given species of plants or animals. In the diagram the normal number is assumed to be 14 (the first and second circles of the

middle row). The number of chromosomes is not always the same in both sexes: in the diagram the male is represented with 13 chromosomes (the third and fourth circles of the middle column). In any given cell the chromosomes occur in pairs having the same size and shape (excluding the odd one): in the diagram these pairs are shown in the middle of the right and of the left columns.

When gametes or germ-cells (ova and sperm) are being produced the chromosomes of each germ mother-cell become sorted and distributed between the cells forming the mature egg (or sperm), each having then only *half* the normal number of chromosomes—7 in each egg and in half of the sperms, and 6 in half of the sperms. The normal number of chromosomes is restored when an egg is fertilized by a sperm.

The middle column shows the possible chromosomal complexes in the four individuals that might result from the fertilization of the two mature ova on the left by the two spermatozoa on the right. There are two possible female zygotes, AC and BC, each with 14 chromosomes but not the same groupings; and there are two possible male zygotes, AD and BD, with 13 chromosomes, but again each group contains a different assortment of the individual chromosomes. Thus each individual contains a combination of chromosomes differing from that of the other three individuals. The chromosomes derived from the two grandmothers are shown in solid black and in stippled, and these are not distributed similarly in the zygotes; neither are the grandfather chromosomes (cross-lined and white) always present in the same kind and number. Therefore, in nature, two children of the same parents would practically never inherit exactly similar groups of chromosomes or characters. However, two twin individuals derived from one egg present identical heredity with the same chromosomal combinations.

elucidated and extended by Professor E. B. Wilson of Columbia and Miss N. M. Stevens at Bryn Mawr. Actually the great difference between the male and female individual were found to be fundamentally due to a difference in the chromosomal composition of the fertilized eggs from

which the sexes arose. Nothing could more strongly emphasize the importance of the chromosomes in the inheritance and development of the individual—they not only determine the inherent composition of the individual but must as well influence and direct the character of its development. (See Fig. 2, page 60)

The Genes

The work of the past twenty-five years has demonstrated in a most remarkable and thorough way the individuality of the chromosomes, and the fact that the chromosome is actually the visible structure containing the hereditary factors or so-called *genes*. This is one of the greatest advances of modern biology. On the basis of this knowledge of the chromosomes a more remarkable progress in the understanding of inheritance has been made during the past quarter century than was accomplished during several centuries before.

Linkage and Chromosomes

The realization that the hereditary units or genes are contained in the chromosomes has been the basis on which an accurate analysis of many of the minute phenomena in inheritance has been accomplished.

In studying the inheritance of a number of characters that were transmitted according to the

Mendelian expectations, Professor William Bateson and his brilliant co-worker, R. C. Punnett, discovered the fact that two characters in the individual may be linked together in their manner of inheritance. For example, in crossing varieties of sweet peas a purple blossom and elongate pollen grains were inherited together in a definite Mendelian way, while a red blossom and round pollen grains were likewise definitely linked together in their inheritance. Following this original discovery a great number of linked characters were found in both animals and plants.

It was soon recognized that a number of characters were linked with one sex, occurring, for example, only in the male and not in the female of the species. These were called "sex-linked" characters. It was thought that this linking together of certain characters must be due to the fact that the genes upon which they depended were contained in the same chromosome—that the genes for all sex-linked characters, for example, were contained in the sex chromosome. Through this linkage, or grouping, of characters Professor Thomas H. Morgan and his associates at Columbia University have been able to unravel many of the most difficult problems in inheritance and have actually contributed an understanding of the mechanism of inheritance which might, with conservatism, be ranked as one of the most important contributions ever made to this subject.

Crossing Over

Morgan's analysis of the composition of the chromosome and its meaning in inheritance ranks in value with Mendel's law itself which inaugurated the modern attack on this problem in 1900. Morgan and his associates, particularly Bridges and Sturtevant, have found in the small fruit fly, *Drosophila*, that large numbers of characters are linked or grouped into four sets, corresponding to the four pairs of chromosomes in the cells of these flies. Such sets of linked characters are not absolutely consistent in their groupings. It occasionally happens that a character which is ordinarily associated with a certain set of other characters becomes disassociated from these and links itself with another set. This occurrence has been called "crossing over" and is due, we believe, on the ground of an enormous amount of experimental evidence, to a gene from one chromosome actually being transferred to another chromosome when the two chromosomes are lying intimately side-by-side in the condition of "synapsis".

The phenomenon of "crossing over" tends to separate or disjoin certain linked characters more frequently than it does others. The further apart the genes for two linked characters lie in the chromosomes, the more likely are they to become disjoined by one of the genes crossing over to another chromosome.

Chromosome Maps

On the basis of this frequency difference Morgan and his associates have actually been able to make a most definite map of the position of the genes in a given chromosome. Chromosomes have been mapped in this way with remarkable accuracy, and the workers are able to predict and to determine experimentally the transfer of certain genes from one chromosome to another. This gives us a most wonderful picture of the minute composition or arrangement of the hereditary stuff and of the manner in which these structures function.

The morphology and physiology of inheritance would now seem to be on a remarkably accurate basis, and we may take great satisfaction in feeling that most important work in bringing this about has been accomplished in this country—and actually in New York City.

Importance of Linkage

Aside from the important purely scientific value of these discoveries there are certain very practical aspects of this phenomenon of linkage in inheritance. For example, it has been found that certain color or types of plumage in particular breeds of chickens may be linked with fecundity or egg-laying ability. By selecting individuals with this particular feather character, one is en-

abled also to select the linked invisible character of fecundity, and, therefore, breed more accurately for egg production. A number of other such examples might easily be cited.

Modification of Germ Characters

This then, from what has been pointed out in a very general way above, is the composition of the hereditary stuff of the individual as established by ancestral combinations. The very practical question now arises: Can this hereditary composition be modified and altered so as to give a new composition? This is certainly a fundamental problem. A number of workers have attempted in various ways to change or modify the hereditary stuff of the germ-cells.

Probably the first really definite modification of the germ-cell was accomplished by Charles R. Bardeen in 1905 when he treated the male germ-cells of frogs with X-ray. These radiations so modified the sperm that when they fertilized normal eggs the eggs developed into deformed and abnormal tadpoles. The injured male germ-cells had modified the quality of the development of the egg. Similar results were obtained by Oscar Hertwig and others by the use of radium. Here also the male germ-cell was injured. The germ-cells of mammals may probably be injured in a somewhat comparable manner. In different ex-

perimental ways I have been able to modify the germ-cells of male guinea pigs so that when these animals are mated with normal females abnormal and defective young result. A number of other investigators have obtained more or less similar results by treating other mammals.

In all of these cases it must be recognized that the actual hereditary composition has not been specifically altered or changed. What has happened seems to be simply an injury of the cell or of the chromatin as a whole so that this material is no longer able to initiate a normal, vigorously developing embryo when combined with the chromatin of a normal egg. It would look as though the chromosomes, like all other living material, may be injured or depressed and may then function either abnormally or in a depressed or weak fashion.

Inheritance of Modifications

The single case which seems to indicate a possible specific modification of the hereditary stuff is the experiment of Michael F. Guyer. In these experiments, the substance of a rabbit's eye-lens was injected into the blood of a hen. The effect of this was to bring about the formation in the hen of a specific "anti-body". It can be shown that the hen's blood, or the serum, now contains something that can dissolve lens-substance. The

next step in the experiment was to inject some serum from the modified blood of the hen into the veins of a pregnant rabbit. The offspring of the rabbit treated with such serum had defective eyes.

Guyer has followed these experiments through a number of years and on a great many animals, and he believes that the introduction of these substances into the body of a rabbit actually alters the germ-cells in some way so that the offspring from such a parent may have defective eyes and lenses. Should this work be fully confirmed it will be the only case which shows a specific alteration in the chromatin resulting from treatment of the germ-cells.

What Does the Germ Plasm Do?

Now what does this hereditary or ancestral composition of the individual do? Does it actually go ahead and develop into the finished product in a fully independent way, or is the hereditary stuff simply the determining basis from which development starts and afterwards must follow through in a manner depending upon the conditions under which it is taking place? In other words, what is the actual relationship between inheritance and development? Before attempting to answer this question we may better consider briefly some of the facts we know about development.

Development

Among the higher animals development follows the combination of a sperm cell or spermatozoon from the male, with an egg derived from the female. This fertilized egg then proceeds to develop, first, by a process of cell multiplication and, later, in addition to this by foldings and differentiation in various directions, until finally the formed body is produced; this then continues to grow to adult size. Most people are only acquainted with a small portion of the actual development of the individual; that is, they know individuals from the time of birth to death, but they know very little about that important early period of development which is taking place before birth. This pre-natal period is actually by far the most important time in development. As the late Professor Charles S. Minot of Harvard has expressed it, more than 95 per cent of the actual development of the individual has probably been accomplished before the time of birth, and growth from babyhood to manhood represents less than five per cent of the important developmental changes which are actually accomplished by the individual. It is easy then to see that these early changes by which the spherical egg—almost microscopic in size—becomes metamorphosed into the seven-pound babe at birth are most astonishing phenomena. We should consider it a very remarkable

thing that this complex process of development actually completes itself so well in so many cases, unless, of course, it were due to a very definite and fixed mechanism which was quite immune to the action of outside influences. In order to discover whether any of the outside influences which make up the "environment" have an effect on the developing egg, a large number of experimental studies have been devised, and the entire field of work known as experimental embryology has been developed around the various phases of this problem.

Good Eggs and Bad

It is well-known that not every egg under the hen hatches into a vigorous chick. Many fail to develop, others hatch into weak, defective chicks which are unable to live, and still others hatch less defective but still inferior chicks which are in many ways unfit for the purposes of the poultryman. Similar facts are well-known to fish culturists. Not every fish egg develops into a normal fish—many eggs die, some develop only a short time and then die, and many of the embryos develop to the point of hatching but are unable to survive as free-swimming fish; but fortunately most of the eggs in a given lot may develop into normal, strong specimens. It is evident that there are actually some "bad eggs" and

this is probably due to a fundamentally defective hereditary composition which does not permit normal development.

Conditions of Development

Aside from the fate of these bad eggs, are the good normal eggs able to develop normally under bad conditions? If the environment be slightly modified from that which is considered normal, a number of the good eggs are affected and begin to develop in an abnormal way. The developing egg depends very certainly upon the nature and condition of the environment in which it develops.

The three important factors in the environment which must be stabilized in order to obtain normal development, are water, the oxygen supply, and the temperature. Animal eggs all require a definite supply of water and if water be removed and they are allowed to dry, development stops and the embryo dies. Developing eggs are also dependent, just as the adult is, on a free supply of oxygen. When the oxygen supply is reduced development becomes slower and will finally stop; but if development continues at the slow rate it will give rise to abnormal structures and deformed individuals.

The eggs of almost all species of animals are disturbed by unusual variations in temperature

during their development. The embryos of mammals are guarded against temperature changes by the mother's body but the eggs of animals that develop outside the body of the parent must have a more or less constant environmental temperature. The eggs of the common fowl must be warmed up to a temperature of about 103°F , and if they are incubated only a few degrees above or below this, they develop abnormally and many of them die. The eggs of some fish develop in very cold water, almost down to freezing, while the eggs of other fish develop only in water from 15° to 20°C . Whenever the usual temperature be either raised or lowered beyond a limited number of degrees, the embryo is unable to develop normally.

Thus, in spite of perfect hereditary composition, the egg is unable to develop into a strong, normal individual in other than a particular environment.

Limitations on Development

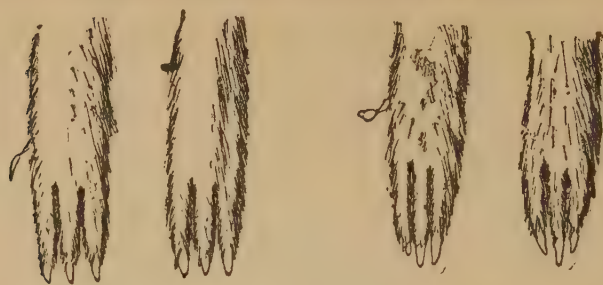
From these facts we may easily surmise that individuals may inherit the possibilities for a number of characters which they are never able to express. One rarely or never develops all the characters for which he may have an hereditary basis. For example, an individual may be said

to inherit the nose from his father or his mother and yet he may develop no nose at all; he may inherit his father's mouth and yet may develop with a harelip and cleft palate, thus in no sense resembling the mouth of his father. It is often difficult to say what we actually have or have not inherited. We simply see the characters which we have been able to express from the fundamental hereditary basis with which we started. We are certainly then a combination of inheritance and development, and the possibilities of neither may be expressed to their fullest extent.

Professor Herbert S. Jennings in his splendid essay "Prometheus" has recently stated the case as follows: "Characteristics are not inherited at all; what one inherits is certain material that under certain conditions will produce a particular characteristic; if these conditions are not supplied, some other characteristic is produced."

Experimental Evidence

It has been experimentally shown that the bases for many characters may be present in the germ-cells and yet the characters be unable to express themselves. I have recently studied a particularly interesting case of this kind in guinea pigs. The guinea pig has three toes on its hind feet and four toes on its front feet—it lacks the big



r A l

r B l



r C l



r D l



r E l



r F l

FIG. III. THE LITTLE TOE IN THE GUINEA PIG

The hind foot of this animal normally has but three toes, the toes corresponding to the thumb and the little toe being absent. In some cases the little toe appears in various degrees of development or expression. In A and B there is a poorly formed rudimentary toe on only one foot; the other foot has only the usual three-toed condition. In C and D there is an extra toe on both hind feet, and the toe is somewhat more strongly developed. In E the condition in both feet is still more pronounced. F shows the perfect development of the little toe, being a four-toed foot lacking only the great toe.

and little toe on the hind foot and the thumb on the front foot. This is a very definite arrangement and probably has existed in the race of guinea pigs for thousands of years. Yet it occasionally happens in stocks of guinea pigs that an individual may occur with an extra toe, representing the little toe of the hind foot. Such individuals may show this little toe as a perfect, well-articulated digit, or else it may be present in all degrees of imperfection down to a tiny toe nail suspended on a mere fiber. The degree of expression or development of the small toe on the hind foot is extremely valuable for study. For if these extra-toed individuals be selected and mated together the occurrence of such toes becomes more frequent and, finally, when animals with perfectly developed little toes are constantly mated together, we derive practically 100 per cent of offspring with four toes on the hind feet. In such a line that had been selected for some time for developing extra toes, an individual finally occurred



FIG. IV. THE THUMB IN THE GUINEA PIG

The front foot of this animal normally has four toes, the toe corresponding to the thumb being absent. G, two front feet showing the very rare occurrence of a thumb, but not quite perfectly formed. The hind feet of this individual show a four-toed condition similar to that in H.

with a 5th finger, representing a thumb, on the front foot. Thus this animal had five fingers on the front feet and four toes on the hind feet, only lacking the great toe on the hind foot which, if present, would have completed the old ancestral pattern of five digits on each foot.

From these experiments it is very probable that the hereditary basis for five digits on every foot is still present in the germ cells of the guinea pig; yet the ordinary guinea pig in the wild state and in captivity develops an extra or fourth toe on the hind feet only in rare cases. The genes or factors for the five digits are in some way unable to effect a development of these digits. It may be that the interaction among the genes has become somewhat modified in the history of the germ cells in guinea pigs so that the expression of these characters has been prevented; yet the genetic basis for the five-toed foot is definitely present in the germ plasm.

An Example from a Laboratory Mutant

In addition to this kind of evidence showing that the actual body characteristics are not necessarily the definite expression of the complete genetic basis, there are other somewhat different experiments which prove the same thing. Morgan found some years ago that among certain breeds of fruit-flies raised in an unusually humid

environment, a germ change or mutation occurred which showed itself in the form of an abnormal or deformed abdomen. This definite genetic character bred as a sex-linked dominant. When flies carrying the abnormal abdomen were transferred to a dry environment they ceased to give rise to offspring with the abnormal abdomen—all developed into perfectly normal specimens. This line of individuals was bred in the dry environment for nine generations as perfectly normal specimens. They were then transferred to the humid environment and immediately gave rise to the abnormal abdomen in the expected fashion. The ordinary strains of fruit-fly bred in the humid environment do not of course give abnormal abdomens. This particular line of flies had a distinct mutation for abnormal abdomen which had arisen in the humid environment. When a generation was bred in a dry environment they failed to exhibit the mutant condition. This case is particularly interesting since it shows that animals with a definite genetic composition may under certain conditions develop perfectly normal bodies, and under other conditions, abnormal bodies. The genotype may be abnormal and the phenotype perfectly normal or, as cited above, the reverse may also be true. A normal genotype may give in a peculiar environment an abnormal phenotype.

Internal and External Factors in Development

From this very brief and simple consideration it seems quite evident that we have made considerable progress during the past quarter century towards an understanding of inheritance and development. At the present time no one familiar with these fields would pretend to assert that we have solved the entire riddle—everyone realizes that much of serious importance is yet left to be accomplished. This field of study is rather in full bloom than in complete fruition. From our present knowledge, which is here very scantily reviewed, we are led to feel that the individual is actually a product of the interaction of two sets of factors which we may call the internal factors and the external factors of development. At the beginning, the internal factors are to be thought of as the genetic or hereditary constitution, and the external factors are the conditions of the environment in which the egg develops. As the embryo or individual progresses in development and becomes more and more complex, some of the external factors may actually be thought of as becoming internal, and as the various organs of the developing body begin to form chemical products within themselves these products actually act or react on other organs of the body, and so the condition becomes most complex and it

is very difficult to say where the internal factors stop and the external factors begin.

Human Inheritance

Finally, we may ask how much is known of that phase of inheritance so important to all of us, human inheritance. In spite of the remarkable advances which have been made through experimental and analytical work on animals and plants, very little accurate knowledge is available at the present time from which we can positively analyze the complexities of human inheritance.

Human inheritance is of course like other animal inheritance, but the method by which we have gained accurate knowledge of the inheritance of certain characters in lower animals has been through experimental analysis and this method is difficult or inapplicable in the case of the human species. The problem is far more complex than one thinking little about it would imagine. We often hear persons speak of their ancestry and relationship in very certain and very definite terms, and they feel that their lineage is quite definite and clear. Yet actually what do these opinions and assertions mean? Take, for example, the case of any one of us: each has two parents, and four grand-parents, and theoretically eight great-grandparents, and so on. When we come to the tenth generation back, provided no matings had

occurred between relatives, one should have had 1024 tenth-generation great-grandparents. This in itself would be quite a community. Even making allowance for the number of relatives among the present population of about 110-million people in the United States, we recognize that ten generations ago an enormous number of people would be required as ancestors but for a great number of cousin marriages—and that means a considerable amount of inbreeding. Thus one individual in an ancestral tree sometimes plays the rôle of several, which means that people have constantly been marrying cousins, so that both consorts frequently go back to some common great-grandparent. Today the people of such countries as Germany, Denmark, and several others, are all fairly close cousins of one another; and this is more or less true for all Europeans. Under such conditions it is difficult to get pure lines for any particular characters; most people are *heterozygous*³ to a great extent.

Defects and Diseases

The hereditary combinations in the human being are very much complicated, and each of us probably has many latent genetic conditions which do not show themselves. A few simple human

³ A heterozygous individual is one whose two parents contributed to his make-up two differing genes with respect to a given character. For example, if one parent had dark eyes

characters have been analyzed in their inheritance in a very clear-cut manner. Some of these are color-blindness, hemophilia or bleeding, albinism, etc. The cases are very few, however, and apply to rather simple genetic conditions. Much is frequently said about the inheritance of various diseases, and no doubt some day inheritance will be seen to play a definite and most important rôle in the complete understanding of various susceptibilities and the expression of different diseases.⁴ At the present time too little is known

and the other blue eyes, the offspring would be heterozygous, even if he had dark eyes like those of one parent. The term homozygous, meaning made up of identical hereditary material from both parents, is equivalent to what we commonly have in mind when we speak of "pure" strains. It is to be noted, however, that whereas in ordinary speech we are apt to think of "pure" or "mixed" as applying to the totality of a strain or breed, the biologist applies the terms homozygous and heterozygous to the separate traits or characteristics of which the individual is made up.

⁴In speaking of the possible inheritance of disease, two kinds of distinction have to be made. First, we must distinguish between the specific diseases, such as tuberculosis or typhoid fever, which are known to result from very definite conditions in the environment, and various defects or deformities, such as color-blindness, hemophilia, brachydactily, and other conditions which appear to be constitutional, and which appear or develop without regard to special conditions, or at least to conditions acting after birth. The second distinction is between a disease, such as typhoid fever or tuberculosis, and the "susceptibility" to the disease. A person may be very susceptible to tuberculosis, for example, and yet remain free from the disease for a long lifetime, if he lives where the specific germs of the disease cannot attack him.

See footnote page 178.

about this subject to warrant very many definite statements.

All of the field of human inheritance is practically open to the future investigator and many problems of huge importance await solution. It is perfectly proper and fair to pause briefly and take stock, but at this time it would scarcely be correct to feel that the chief problems of inheritance and development have been pretty well worked out. It is rather nearer the truth to say that this field still offers a magnificent opportunity for grand discoveries.

FROM TEST TUBES TO LIVING
THINGS

Hugh S. Taylor, D. Sc.

CHAPTER III

FROM TEST TUBES TO LIVING THINGS

The human body, in its material aspects, can be regarded as a vast chemical laboratory, in which various interesting chemical processes are going on, many of great complexity. Chemistry, in its material aspects (for it has also spiritual values), is concerned mainly with two sets of problems: on the one hand, there are those pertaining to man's possessions, his clothing, his ornament, his dwelling and the multitudinous material features of his complex civilization. On the other hand, there are the problems that arise from the life that is within man's body and the need for sustaining that life. These two sets of problems animate the whole of chemical effort from the earliest pages of its historical record.

We have all heard of the alchemists, their search for the philosopher's stone and their endeavors to transmute the base metals into gold. But side by side with that effort there was developing the art of the medicine man, largely sustained by those versed in the black art of chemistry. This movement became so pronounced that in the

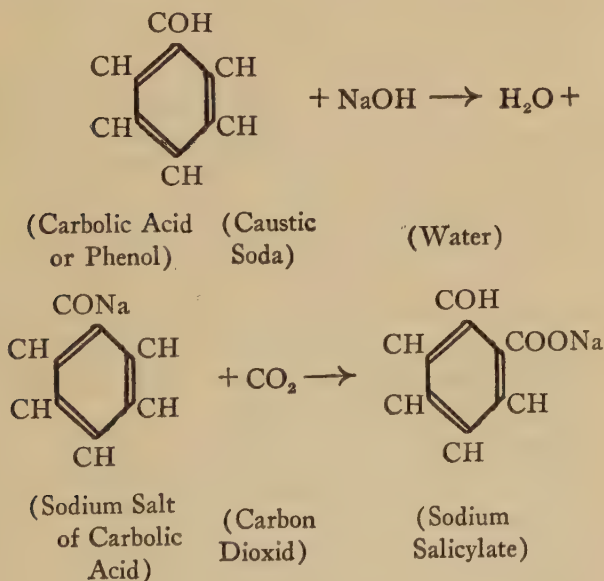
Iatro-chemical age—i. e., the period of medical chemistry—it formed the major object of the chemist's study.

Paracelsus (1493-1541) insisted that life was essentially a chemical process. His service to chemistry consisted essentially in this, that he induced the alchemist to give up the search for gold and to test his skill in the preparation of remedies for human ills. His service to medicine lay in his insistence that the physician should know something of chemistry. This mutual dependence of chemistry and medicine has increased with the progress of time so that now the science of chemistry is a necessary preliminary to the science of medicine, considered here in its broadest aspects *as the science of the production and maintenance of good health*. It is part of my task to show this interdependence and to indicate how the exact scientific methods of the chemist are likewise at the disposal of the medical man. We may deal first with the method of synthesis.

The Chemistry of Drugs

Primitive medicines were found in plants and herbs. Pharmaceutical chemistry sprang from their study. From time to time specifics of inorganic or mineral nature were added. From such natural sources the active principles were isolated and studied. Then, when the synthetic

organic chemist learned his trade of building the more complex molecules from their component parts he succeeded in many cases in producing synthetically and in pure form what is found in nature in small amounts and admixed with other non-medicinal materials. Thus, *salicylic acid*



was probably the first medicine to be prepared synthetically. It is found in nature as *salicin* in the bark of white poplar and of willow. Infusions of these barks have long been used for rheumatism. Nowadays, solutions of the pure salts, *potassium* or *sodium salicylate*, are used for

the same purpose. The chemist's method of building such a salt, from carbolic acid which is found in coal tar, is illustrated by the diagram on the preceding page.

From the sodium salt we can obtain the corresponding acid, salicylic acid,



Such a substance is the starting point for numerous products of inestimable benefit to man. Thus, if we replace the OH in this compound by a group consisting of CH_3COO —we obtain the compound *acetyl salicylic acid*, universally known as *aspirin*, a specific for neuralgia and headaches, gout and rheumatism, and for lowering the body temperature in fevers. By combining salicylic acid with *methanol* or wood alcohol the chemist obtains *methyl salicylate*, which the general public recognises under the name “oil of wintergreen”, a natural oil obtained by distilling an American evergreen plant, *Gaultheria procumbens*. This oil can be applied externally to lower body temperatures and is an easily recognized constituent of some dentrifices.

Improving on Nature

Sleep is produced by the use of morphin. Morphin belongs to a class of organic substances found in various plants and known as alkaloids. The

name means "like alkali", and indicates that in their chemical reaction they somewhat resemble soda and potash. They all contain nitrogen, and they are all more or less active poisons. Alkaloids are the essential principles in coffee (cafein), tobacco (nicotin), belladonna (atropin) and other "drugs", as well as in opium (morphin). As is well known, however, dangerous and undesirable after-effects are also produced by morphin, in addition to sleep, as well as a craving for the drug. The chemist here has intervened to improve on nature's remedy and has provided soporifics such as *veronal* and *luminal*, which do not have the harmful qualities of the natural alkaloid.

Oxid of arsenic is an inorganic poison, but, in suitable doses, it has long been known as a specific for anemia and for certain skin diseases. From this as a starting point the chemist attempted to form compounds containing arsenic and organic groups which should have greater activity than the oxid without its poisonous character. In Ehrlich's laboratory in Germany many hundreds of such compounds were studied until Hata, a Japanese student, found that the 606th preparation was an antidote to syphilis. Later it became known as *salvarsan*. Many such preparations are now available, *neo-arsphenamin*, *sulpharsphenamin* and *arsenol*, all organic compounds containing arsenic.

Gland Secretions

We may now turn for a moment to animal sources of beneficent bodies and thus come into contact with other problems than those of specifics for disease. In the suprarenal gland, a ductless gland situated at the end of the kidneys in most backboned animals, there is found a compound which has been isolated and purified and which is known as adrenin. Its importance arises from two of its properties. First, it produces an increase in blood pressure and is therefore of great use as a stimulant. Professor E. G. Conklin of Princeton University attributes lack of muscular tone and "loss of nerve", such as occur in neurasthenia, "shell-shock", etc., to adrenin-insufficiency. Second, when injected into tissue, adrenin reduces the blood circulation in its vicinity. Bleeding during an operation can thus be prevented. An alkaloid from the coco-bush¹ of South America, *cocain*, can also be used for this latter purpose. The organic chemist however, has improved on the natural product, synthetic *novocain* or a mixture of novocain with adrenin being utilized to produce local narcosis or insensibility, and to prevent bleeding.

Pure adrenin has been analyzed and found to have the formula $C_9H_{13}O_3N$. This tells us only

¹ This is not to be confused with the coco-palm, the source of coconuts, nor with the cacao plant, from which we obtain cocoa and chocolate. Ed.

that the elements Carbon, Hydrogen, Oxygen and Nitrogen occur in adrenin in certain proportions. It does not tell us how the nine atoms of carbon, the thirteen atoms of hydrogen, and so on, are arranged in relation to one another. The structure of the adrenin molecule has, however, been ascertained; whereupon a German chemist, Friedrich Stolz, of Höchst succeeded in producing it synthetically.

Adrenin is an example of the so-called "internal secretions" or *hormones*, of which there are several distinct kinds in the mammalian body. The designation "internal secretions" refers to the fact that these substances are given off or *secreted* by the cells of special organs, like the secretions of the liver, the salivary glands, and other glands; but that instead of coming to the surface through special ducts or tubes they are absorbed by the blood and so distributed to all parts of the body. The structures in which these secretions are found (the adrenals, the thyroid, the pituitary, etc.) are sometimes spoken of as the *ductless* glands. The name "hormone" comes from the Greek and suggests that these substances somehow rouse or activate various organs of the body.

Insulin

Before all the mysteries of these glandular secretions or *hormones* are understood, a vast

amount of joint investigative effort is yet needed upon the part of the chemist and the doctor. We hear from time to time, however, news which speaks of progress. It is but recently that we learned of *insulin*, the product of the pancreas² discovered by F. G. Banting and C. H. Best in the laboratory of J. J. R. McLeod at Toronto. At present insulin is prepared from the pancreas glands of various animals; its constitution is unknown but it is being studied.³ The composition learned, the effort to synthesize insulin will be undertaken in order that a sufficient quantity of this material may be accessible in carrying on the great fight against the dread disease diabetes.

Thyroxin

The secretion of the *thyroid* gland, found in the neck near the "Adam's apple," causes rapid heart beat, raises the temperature, and increases metabolism, the chemical processes going on in the cells of the body. Excessive secretion gives

² The pancreas (the "belly sweetbread" of the meat shop) has long been known as a gland that produces ferments of direct importance in the intestinal digestion of food. These ferments reach the intestine by way of ducts. Insulin is produced in little patches or "islands" of tissue scattered throughout the pancreas, and is absorbed into the blood vessels that penetrate the gland. The pancreas as a whole is thus a double organ, an orthodox gland with ducts, and a ductless gland, or rather an assemblage of tiny ductless glands.

³ Insulin has recently been prepared in a pure crystalline form by Dr. J. J. Abel of Johns Hopkins University.

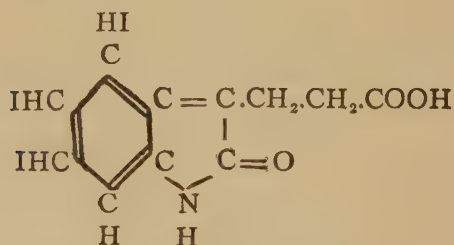
rise to goitre and protruding eyeballs. Subnormal secretion on the other hand, leads to lowered muscular activity and dullness of mind. In a child it prevents the normal development of body and mind, and in extreme cases leads to the idiotic dwarf or *cretin*.

The active principle of this secretion was isolated and identified by Dr. E. C. Kendall, who now for a decade has explored this problem of *thyroxin*, its extraction and isolation from the glands of animals and its chemical constitution. He is even now engaged upon its synthesis. This research has involved the preparation of a variety of organic compounds having the same chemical formula as thyroxin ($C_{11}H_{10}O_3NI_3$),⁴ but without the distinctive properties of the natural product. Gradually, by a process of elimination the field of possibilities is narrowed and the goal more nearly approached. Any day we may now hear that the organic chemist has triumphed once more and produced thyroxin by his synthetical art.

The results of Kendall's work have a wide bearing on our understanding and control of the chemical life processes. As already said above,

⁴It is possible for the chemist to produce a very large number of different compounds having the same proportions of carbon, nitrogen, iodine, and so on. The properties of each compound would depend upon the *structure* of the molecule, the way in which the atoms are arranged or linked up with one another.

one function of the thyroid gland secretion is to increase the rate of *metabolism*, the process whereby food is assimilated and the life within us is sustained. The injection of 1 mg. of thyroxin will produce an increase in the carbon dioxid output of approximately 400,000 mg. Thyroxin therefore appears to exert its influence by acting as a *catalyst*, an agent which assists or accelerates chemical changes without itself undergoing any permanent alteration. We may well ask, therefore, whether, with the achievement of synthetic thyroxin, there may not come also a deeper knowledge of the mechanism whereby starch, protein and fats are converted to blood and tissue. The structure of the thyroxin molecule is represented by this diagram:



In what part of this molecule resides the key that unravels the complicated structure of the nutrients, simplifies them so that they may be absorbed into the stream of life?

Enzymes

Thus far we have considered the problems of medicine in their appeal to the synthetic organic chemist, and the attempt to reproduce in the test tube the manifold products of living things or improvements thereon. The problems outlined in the preceding paragraph bring us to yet another group of studies of life processes in which the results have their counterparts, their parallels and their exemplifications in ordinary chemical processes. It is a matter of common knowledge that a variety of common processes are produced by a class of bodies known as *enzymes*. An Italian priest, the Abbé Spallanzani, showed in 1857 that the gastric or stomach juices were able to liquefy pieces of meat outside the living organism. In 1830, Dubrunfaut prepared an extract of malt which would convert starch into sugar. Payen and Persoz in 1833 isolated a substance from the watery extract of barley which they termed *diastase* and which would also lead to the conversion of starch into sugar. Schwann (1810-1882) in 1834 isolated *pepsin* from the gastric juices and showed that it had the power of digesting the protein content of food. It was not until 1896, however, that Buchner ruptured yeast-cells and showed that a substance which he called *zymase* could thus be expressed from the

living cells, that enzymes, the essential substances which bring about the chemical changes, could be properly differentiated from the ferments, the living bodies that produce the enzymes.⁵ Thus we learned that enzymes were, in fact, chemical substances secreted or excreted by living cells and possessing chemical properties of great significance in all vital processes, though themselves non-vital.

Colloids

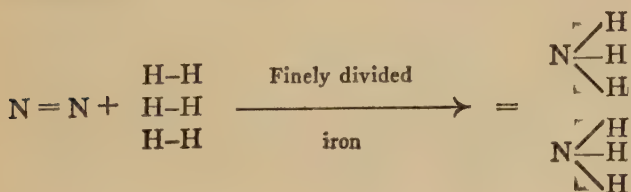
Now, the synthetic organic chemist has thus far failed entirely to synthesize such products in the laboratory. Hence, it has been necessary to adopt other means than synthesis to arrive at an understanding of their activity in life processes. The physical chemist has provided these alternative aids to medical science. He has succeeded in demonstrating that these bodies are *colloidal* in nature. The term *colloid*, originally meaning glue-like, is now applied generally to solid bodies in an extremely fine state of division, a much finer state of division than can readily be attained by processes of physical subdivision, such as grinding. A little thought will convince anyone that, as a particle of matter is rendered finer and finer by being broken and subdivided into smaller and

⁵ The distinction between ferments and enzymes is today only of historic interest. All living cells contain enzymes, and therefore have the capacity to bring about fermentations. Ed.

smaller bits, the relative amount of the *surface* of the material becomes more and more pronounced. Thus, an inch cube has a surface of six square inches. If such a cube be divided into 1,000 equal cubes the surface area will be sixty square inches or 10 times as great for the same mass of material. If each of the small cubes be further subdivided in the same manner the total area is again raised ten times or to 600 square inches. Now all these colloidal solids possess this large ratio of surface to mass, and it is the properties of the surface which determine their chemical activity.

Catalysis

Two examples may be cited from among many chemical processes to illustrate this activity of extended surfaces. Nitrogen, which constitutes more than four fifths of the atmosphere, is a very inert gas, and does not readily combine with other elements. Yet this nitrogen in the presence of finely divided iron can be rendered so active that it will readily combine with hydrogen to form ammonia.

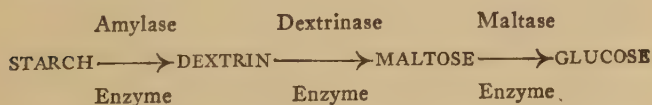


Upon this fact is based the Haber process of nitrogen fixation. Massive iron is quite inactive in this respect: the iron must be finely divided. Similarly, hydrogen can readily be added to a liquid fat like cottonseed oil to produce a semi-solid fat of the type of Crisco or Snowdrift, provided finely divided nickel be suspended in the oil whilst the hydrogen is being passed through it. This is the modern process of fat hardening practised by many soap and vegetable-lard manufacturers. It cannot be achieved industrially by any other chemical process, as 100 years of failures eloquently testify. As in the case of iron, the reaction does not take place when massive nickel is used. Yet it proceeds with the utmost readiness when finely divided nickel is present as the catalyst or catalytic agent.

Nature abounds in such "catalytic" agents, that is, substances *which assist or accelerate chemical changes without themselves undergoing any permanent alteration*. Catalysts are able to bring about large amounts of reaction, themselves remaining perennially fresh and efficient. Thus, in the blood, we find the enzyme, *thrombase*, whose activity consists in the clotting of albuminous materials. *Myosinase* acts as a clotting agent in the muscle serum. These act like the enzyme rennet, which is obtained from the stomach of the calf and is widely used for clotting the curd out of milk, in cheese making.

Digestion of Starch

There are also the enzymes which convert starches into sugar by causing them to combine with water and to break down into simpler fragments. Here are to be found problems of entrancing interest since each individual enzyme appears to possess its own special function and no other. The enzyme *amylase* takes the starch through a portion of its simplification, to the formation of dextrans; the broken-down starch in the form of dextrin is then acted upon by the enzyme *dextrinase* to yield maltose, which then by the action of the enzyme *maltase* yields the sugar glucose:



No one enzyme will do the work of any other. Each has its own peculiar functions and its own peculiar limitations.

Special Enzymes

Mention has already been made of *pepsin* as the most important enzyme concerned in gastric digestion. *Trypsin* is an important enzyme of the pancreas; it breaks albuminous materials into similar compounds. In the liver there are pro-

duced enzymes whose function it is to oxidize or burn up the materials passing through. Gout and similar disorders result from the failure of such enzymes to function properly. Such oxidizing enzymes are present in the light-producing mechanism of the firefly and of the many other species of luminous animals. Dr. Edmund Newton Harvey, of Princeton, recognized this and by providing the enzyme with renewed quantities of material to be oxidized and with oxygen he was able to show that such cold light could be produced continuously over long periods of time, not intermittently as normally obtains in nature.

The great service which chemistry has been able to render has been to demonstrate the laws underlying the chemical reactivity of vital processes. The chemist has thus facilitated the study of the natural processes by the biological chemist or bio-chemist, who in his turn has handed on his conclusions to the medical man for the better control of the health and bodily welfare of the community.

The Relation of Light to Chemical Processes

It is a commonplace now to insist on the need of sunshine for good healthy racial stock. All the laws and ordinances governing smoke abatement in our cities are based on the need for sunshine. "Sunshine or cod-liver oil," one might say, if our

children are not to suffer undue incidence of rickets. Sunshine and fresh air for our tubercular patients is axiomatic in our sanatoria. What has chemistry to say to such agencies of the medical man for health maintenance?

The photo-chemist has shown for a century from his laboratory experiments that the chemical actions are often accelerated by light. He learned also that certain reactions not sensitive to light could be sensitized by the addition of certain light-absorbing constituents to the reacting system. Similar conditions obtain in the human system. Light increases the formation of tissue in wounds. This tissue is at first red but later turns white. The raying of open wounds to promote such growth of tissue is one illustration of light acceleration in vital processes. Lupus or tuberculosis of the skin responds to light treatment of this kind. Blood absorbs light of many different wave-lengths. It is not yet known how large a part such light plays in the chemical processes of the blood stream. The skin protects the blood stream from the injurious short wave lengths, those which produce sunburn on the skin, since these short length waves cannot penetrate very deeply. But the blood can be sensitized to the longer wave-lengths, just as with the chemical reaction in a test-tube. If a certain sensitizing agent, *haematoporphyrin*, "blood-purple", be present in the blood, the light of longer wave

lengths normally inactive, causes changes in the blood leading to very toxic effects. Such poisonous effects, due to light acting on sensitized living matter may also be observed with certain bacteria. Normally insensitive to illumination by visible light, these bacteria may be destroyed by staining them with dyestuffs and then exposing them to visible light. A parallel process in the inorganic world is that of rendering photographic plates sensitive to green, yellow, or red light by bathing the emulsion in suitable dyestuffs, the process used in producing orthochromatic and panchromatic plates.

Ultra-Violet Rays

The medical man is only beginning to understand the mechanism whereby the ultra-violet light of the sun is absorbed into the system to produce beneficial effects in bone-formation, as in the cure of rickets, or in tuberculosis of the bones. It is known that the effect is similar to that produced by administering cod-liver oil. There is some evidence to support the view that this effect may be attributed to the action of light on *cholesterol*, a substance which is present in the oily materials of the skin, and which is absorbed into the system when acted upon by light. Cod-liver oil also contains cholesterol and it has been shown that the efficacy of cod-liver oil may

be enhanced by suitable irradiation with light [See pp. 123 ff.].

The Chemistry of Vision

The chemistry of eyesight forms another phase of the general problem of photo-action, of which much is understood and still more unknown. Much of the chemistry of the retina and its power of producing impressions on the brain yet remains to be elucidated by ingenious investigators. We need to know yet more of the problems of eye-fatigue, of color sense and of color blindness. Here also the studies of chemical photo-sensitisation may be helpful.

X-Rays and Radium

The chemist demonstrated the destructive action of X-rays on a wide variety of chemical compounds. Everyone now knows of the same utilization of X-rays, or of gamma-rays of radium, which are also X-rays from another source, to destroy tissue in cancerous growths. The X-rays are light of very short wave-lengths and great penetrating power and have thus a wider radius of action than normal visible light.

The Chemistry of Food Values

Feminine fashion has recently decreed that stricter attention should be paid to the nutritional

values of the various foods consumed. Butter and sugar, potatoes and candy have acquired new terrors for numbers of our sisters. Our restaurants obligingly tell us how many calories may be purchased with our bacon and beans so that economy both of finances and of *avoirdupois* may effectively be observed. The basic principles upon which such calculations are made are the province of thermo-chemistry. The great French chemist, Lavoisier, victim of the French Revolution, conducted the earliest experiments in animal calorimetry, by placing mice in a space hollowed out in a block of ice and determining the amount of ice melted in a given interval of time. From these results could be deduced the energy requirements of the animal, which naturally vary with its activities. Such energy requisites are supplied by the food we eat, since all processes of food consumption generate heat. In the last analysis, all such heat quantities can be referred back to the heat which is produced when carbon, hydrogen and nitrogen are burned to form their products of oxidation. The fundamental principles are the province of the chemist; their application is the province of the nutritional expert, whose path is not without many complications by reason of the varied products which one and the same food—for example, protein—may yield in different vital systems.

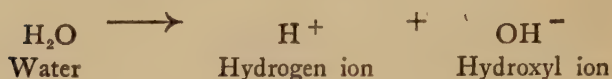
Inorganic Substances in Vital Processes

No record of chemistry as the handmaiden of medical science would be fully representative were not some consideration given to the functions of inorganic substances in the processes of organic life. That branch of chemical science now known as physical chemistry has furnished medicine with new points of view as to the rôle of these inorganic constituents found in the blood stream, the saliva, the stomach and intestines. The same constituents in food and drink call for further study and elucidation.

Acidity and Alkalinity

Every housekeeper knows that when milk has become slightly sour, it can be made to serve by the addition of a little baking soda. Every farmer knows that a sour soil can be remedied by the use of lime. The acidity or alkalinity of soil, of water used for washing, of fluids used in tanning and in other industrial processes, is of great importance in influencing the results sought. In the same way, all the body fluids are delicately adjusted as to acidity or alkalinity. Each fluid operates most successfully at a determinable optimum concentration either of acid or of alkali. Modern physical chemistry has taught that the common constituent of water and

all acids is the *hydrogen ion*, an atom of hydrogen which has been shorn of an elementary electric charge. In water this charge has been given up to the other constituent of the water molecule, what the chemist terms the *hydroxyl ion*, which thus acquires a negative electrical charge. In pure water, H_2O , we have therefore a small but perfectly definite and equal concentration of hydrogen ions and hydroxyl ions:



Ion Concentrations

The chemist has determined these concentrations and has found that at room temperature there are 1 gram of hydrogen ions and 17 grams of hydroxyl ions in 10 million ($=10^7$) litres of water. Since hydroxyl ions are seventeen times as heavy as hydrogen ions this is equivalent to saying that there are equal *numbers* of these electrically charged particles in neutral water. We define neutrality as that state of affairs in which there are equal numbers of these two kinds of ions. Additions of acids increases the concentration of hydrogen ions and, correspondingly, decreases the concentration of hydroxyl ions. Addition of alkalies, on the other hand, like carbonate of soda, increases the concentration of

hydroxyl ions and likewise decreases the concentration of the hydrogen ions, since the product of the two is always the same as in pure water, namely $10^{-7} \times 10^{-7} = 10^{-14}$.

The chemist and the biologist employ a short-hand method of stating these concentrations. In water, where there is 1 gram of hydrogen in 10 millions $= 10^7$ litres of water, the formula $\text{pH} = 7$ is used.⁶

Hydrogen Ion Concentration of Body Fluids

The saliva is nearly neutral, its pH is approximately 7. The gastric juice contains hydrochloric acid, its pH is approximately 1. The concentration depends on the rate of secretion and the rate of combination and dilution. Hyper-acidity, a well known complaint, is due to too high a concentration of acid; hypo-acidity is a term used to designate low acidity or scanty secretion of the gastric juice. Low acidity occurs in a variety of diseases such as cancer, anemia,

⁶ In the expression $\text{pH} = 7$ (which is read pee-aitch equals seven) the seven represents the power to which 10 must be raised to yield the volume (10 million litres) of liquid containing one gram of hydrogen ions. Acids contain more hydrogen ions than water, so the volume containing one gram of hydrogen ions is less than 10^7 . Acids accordingly have a pH which is less than seven. Thus, an acid which contains one gram of hydrogen ions in 1000 $= 10^3$ litres has a $\text{pH} = 3$. Alkalies have a pH greater than seven. More than 10^7 litres of an alkaline solution are always required to contain one gram of hydrogen ions.

disturbances of the gall-bladder, heart disease, and in various deficiency diseases such as beriberi and pellagra. The digestion process depends not on the *amount* of acid secreted but on its *concentration*.

Chemists have devised various methods of measuring the hydrogen ion concentration, and these have been adapted by the biologist and the doctor to the determination of pH values after test-meals, thus obtaining useful information with respect to the source of digestive troubles. The pH is of importance, also, since many bacteria cannot exist in media of too acid a nature. The typhoid group cannot exist in juices with a pH less than 4. For similar reasons the pH of natural waters is very important.

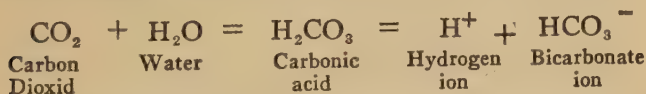
Bicarbonate of soda is secreted by the pancreas and by the intestinal glands. This tends to neutralize the hydrochloric acid of the stomach juices, the acid content decreasing on the way from the stomach down. The pH determination of the urine forms an important method of ascertaining how the various digestive organs are carrying on their different functions.

Hydrogen Ion concentration of the Blood

In the body, the pH value of the blood is remarkably constant. There are two centers which regulate this pH content, the liver, with

its secretions of phosphate and carbonate,¹ and the nerve center controlling respiration.

When a person increases his exertions, the tissues give off an increased amount of carbon dioxid, which is absorbed by the blood. Since carbon dioxid forms an acid with water, carbonic acid, the hydrogen ion concentration in the blood is increased.



When hydrogen ions increase in the blood, the blood flowing through the respiratory center stimulates it to increased activity. As a result, the individual breathes faster, carbon dioxid is expelled from the blood, thus again lowering the hydrogen ion concentration. We breathe faster after running because of this automatic mechanism, not because we feel any "need" for more oxygen.

A practical application of this mechanism has been recently developed by Prof. Lawrence J. Henderson of Harvard, who forces carbon dioxid into the lungs of an asphyxiated or drowned person in order to stimulate the breathing center.

Other Kinds of Ions

Ions other than hydrogen ions are also of fundamental importance in the chemistry of the blood

processes. The calcium ion has been the object of much study, since its reduction below the normal value may result in rickets. In epileptic patients this reduction may lead to a spasmodic contraction of the muscles resembling tetanus or lockjaw.

Sodium, potassium, magnesium, and chlorine ions are also found in the blood. These are all delicately balanced in ratio; alterations in the adjustment of any balance lead to marked effects on the subject. Too large an increase in potassium ion causes the heart to become paralyzed and the rate of heart-beat drops to zero. Calcium ions are also extremely toxic and can only be increased gradually. For continued maintenance of both rate and force of heart-beat, hydrogen, sodium and calcium ions are all essential and normally are present in a certain balanced ratio. In certain experiments the late Jacques Loeb, a famous biologist, showed that the heart rhythm is determined by the balanced ratios of different kinds of ions. The heart of a turtle was cut into strips, and each strip was placed in a different solution. The pieces of heart muscle continued to contract rhythmically for days and weeks. In each dish the rate of contraction can be changed at will by adding one or another solution.

This balance holds also in the cases of lower organisms, as pointed out by Loeb. He showed

that certain marine animals are killed if placed in a solution of sodium chlorid (common salt) or calcium chlorid (a related lime salt which is also present in sea water), even when the density of the solution was identical with that of sea water. Yet these same animals flourished when there was a definite ratio of sodium to calcium. Dr. G. H. Clowes of Indianapolis indicated a similar effect with these salts injected into the veins of rats. It is known that the stability of various colloid systems are also affected by such ionic ratios.

Research and Life

These examples, drawn from several fields of chemical and medical endeavor, should suffice to show how intimately associated chemistry and medicine are; how every advance in the general field of chemical processes can be utilized to deepen our knowledge of the phenomena observed in the field of vital processes; and how the certain laws of inanimate atoms and molecules are transferable to the processes of living things.

The qualities of research and investigation that characterize the chemist have produced trustworthy results that have affected our daily activities in industry, in commerce, in administration. The same qualities must be applied to problems of bodily health and well-being. They

have indeed been applied with wonderful benefits to all. We cannot make living substances in the laboratory, but certain aspects of life we can understand only by the method of the laboratory. These methods are preeminently the methods of experiment, and no others have yielded comparable results.

WHAT WE HAVE LEARNED
ABOUT NUTRITION

Walter H. Eddy, Ph.D.

CHAPTER IV

WHAT WE HAVE LEARNED ABOUT NUTRITION

In 1906, F. G. Hopkins of Cambridge, England, first suggested that our food must include not only meats or meat substitutes, starches and sugars, fats and mineral salts, but that there must also be present certain substances too small in amount for chemical assay but essential to health. He called these factors "food accessories". Later Casimir Funk christened one of these factors "vitamin" and the vitamin hypothesis was born; it has undergone a rapid development in the last twenty years.

Stimulation of Experimental Study

There are two results of this hypothesis that have made the past quarter century unique in the progress of nutritional science. First, the development of the "feeding test" with white rats, pigeons, guinea-pigs, etc., into a chemical tool of tremendous efficiency.

It was C. Eijkman who in 1898 laid the foundation for the elimination of the oriental scourge

known as beri-beri by producing an identical disease in fowls and thus providing a means of testing curative factors and dosage. The identity of rat rickets and human rickets means that we owe to the white rat much of the spectacular progress which made the late Dr. Howland suggest that a few years hence we will be unable to educate hospital interns in the treatment of this disease because cases in human beings will be non-existent.¹ It is to the guinea-pig again that we owe the régime of orange or tomato juice that is eliminating scurvy from the ills of babydom.

It may well be that orange juice and tomato juice constitute desirable parts of our diet because, as many advertising specialists tell us, they are "natural". But it is well to note that for many centuries the mass of human beings upon the earth knew neither the orange nor the tomato; and for vast numbers neither of these fruits is today available. Moreover, it was by means of experiments upon animals that their importance for healthy development was established.

The second great result of the vitamin hypothesis has been to enlist as never before coopera-

¹ There is little need for educating doctors in the treatment of diseases that are being, or can be, eliminated. Most of the practicing physicians in this country today have never seen a case of smallpox. A very large proportion of our physicians are not likely to recognize a case of smallpox when it shows itself, unless there are extraneous reasons for suspecting its presence. This is no loss, however, if we make systematic use of our resources for preventing the disease. Ed.

tion between different branches of science in the pursuit of nutritional problems. In 1898, when Chittenden was first introducing biochemistry into American universities, the workers of note in the field of nutrition could be counted on the fingers of two hands, and most of them were physiologists. At that time the theory that much of disease was bacterial in origin had greatly awakened the medical practitioner to interest in bacteriology, but with a few exceptions such as the problems of diabetes and gout, or in the development of cathartics, the medical men as a whole had seen little to interest them in the field of nutrition. The idea of a dietary origin of disease, and indeed the idea of preventive medicine, was in its infancy.

Rickets

I have already referred to the spectacular progress that has been made in the field of rickets. I know no better example of effective coordination of effort, and it illustrates how the vitamin theory has stimulated the bringing together of the results of research from different fields of study. In England in 1908 G. M. Findlay had reported experiments which seemed to indicate that "confinement with consequent lack of exercise is the main factor in causing the disease of rickets". It was, however, at the time a matter

of common medical knowledge that cod-liver oil was a specific for this disease. Following the demonstration by E. V. McCollum in 1915 of the existence of fat-soluble vitamin (A) in butter and eggs, studies of other fats had shown that cod-liver oil was our very richest natural source of this vitamin. These facts stimulated skepticism of Findlay's views and strongly suggested that rickets might be due to lack of vitamin in the diet, and that since cod-liver oil was curative the vitamin might be vitamin A.

To settle this point the British Medical Research Council allotted to Dr. E. Mellanby the problem of determining whether rickets is not primarily due to the deficiency of vitamin A in the diet. His experiments seemed to confirm this viewpoint, and in 1919 the Council published his results. In this way the sanction of official medical opinion in England was given to the theory that rickets owes its origin to a deficiency in vitamin A.

Team Work in Research

Meanwhile two groups of workers in this country had become intensely interested in the problem. E. V. McCollum and Nina Simmonds had found in 1917 that rats on certain cereal diets developed beaded ribs and that unless calcium salts were added to these diets, a normal skeleton

would not develop. To make sure that these abnormalities in the ribs were like those of humans afflicted with rickets, they enlisted the cooperation of Doctors Howland, Park and Shipley of the Pediatrics department of Johns Hopkins. In New York Henry C. Sherman had been keenly interested in the place of mineral salts in the diet, and had found by analysis of over 200 diets that the substance most apt to be missing in the mineral category was calcium. Being properly curious as to whether we need vitamins to enable us to use the calcium in bone manufacture, he set about devising diets in which the factors associated with calcium should be the variables. Two of his diets were composed of ingredients entirely lacking in vitamins of any sort but varying in the amount of phosphorus. The amount of calcium in these two diets was the same. On the low phosphorus diet his rats developed rickets, but on the high phosphorus one no such symptoms appeared.

Sherman like McCollum was a chemist. He needed the cooperation of methodically trained workers in histology to make sure that his rat lesions were rachitic and found his collaborator in Dr. Alvin M. Pappenheimer, a pathologist. Soon a group had formed in New York including Henry C. Sherman, Alfred Hess, Alvin M. Pappenheimer and Adolf Zucker with a geographical headquarters in Dr. J. W. Jobling's Department

of Pathology at the College of Physicians and Surgeons. Thus when the Mellanby report appeared there were two teams of workers all ready to test and evaluate his work, teams equipped to utilize all the tools of scientific research needed for this purpose and to work rapidly and accurately.

Multiple Causes of Disease

What have we learned as a result? First, that there are several possible causes of rickets, for we can now produce it by normal calcium and low phosphorus in the diet, or by low calcium and normal phosphorus. If the diet lacks a proper *balance* of these two factors we can prevent the appearance of the disease by treatment with cod-liver oil or egg yolk, but the factor in these substances is not vitamin A, as Mellanby thought, but a new vitamin known as D. Or again, we can prevent it by exposing the patient to the direct rays of the sun.

This latest discovery has been productive of amazing results. First we have found that these rays must impinge directly upon the patient, for when screened through window glass they lose their efficiency. What part of sunlight fails to go through glass? The answer is, certain rays known as the ultra-violet and ranging in wave length from 200 to 300 millimicrons. Here then

was the explanation of high incidence of rickets in winter and lower rate in summer. The mercury vapor lamp was now developed to provide artificial sunlight.

Storing Sunlight in Food

Not only is an organism which is exposed to the ultra-violet rays thereby protected against rickets, but also the organism which eats food that has been exposed to these rays. A standard diet is prepared to contain all the food elements except vitamin D. This is supplied to the experimental animals. In the dark, these animals develop rickets; in the sunshine, under glass, they develop rickets. In the open sunshine, or in the ultra-violet rays of the mercury vapor lamp, they develop normally, free from rickets.

The year 1925 will be significant in the history of our progress for the almost simultaneous announcement by Alfred Hess of New York and H. Steenbock of Wisconsin of an important discovery: Not only would the ultra-violet rays protect from rickets; the subject who uses the deficient diet after this has been exposed to the ultra-violet rays is also protected. We know now that the addition to the diet of 5 per cent of milk powder which has been so treated by the ultra-violet rays will also prevent rickets, and that foods so different as lettuce, flour and milk all take on

this power as the result of a few minutes submission to the beams of the mercury vapor lamp.

Sunlight and Health

During the past week I read an article by Steenbock, in which he invokes the adage "make hay while the sun shines" and supports it by showing that hay cured in bright sunlight is a remedy for rickets in animals, whereas hay cured in the dark or in the absence of sunlight is not. Smoke screens over our cities have now a new menace to health for they keep us from the healing and protective rays of sunlight. Even hens' eggs lose their power to protect against rickets unless we let the hens lie in the sun some part of each day.

The work in this country which has developed these amazing results was started by the two groups to which I referred above, but now there are many fields of science cooperating. The physicist has been attracted by the sun ray developments. The physical chemists are trying to tell us how the ultra-violet ray or how the vitamin makes us precipitate the calcium and phosphorus we carry in our blood in the cartilage of our bones. Even commerce is concerned, for I have on my desk now two samples or panes of glass developed to make possible solaria which will permit both visible rays and ultra-violet rays to

penetrate to the patients protected by their covering.

The story of rickets then not only is a triumph of modern nutritional science, an example of a benefit from the development of the vitamin hypothesis, but makes clear the contention that now as never before do we find science making advances through team work, with the benefits that always result when we concentrate efforts and abilities upon a single problem. Many other examples could be selected, like the stories of beriberi and of scurvy, from the science of the past two decades to support this contention. But I have another thesis to develop.

Other Problems in Nutrition

So striking and practical have been the actual facts acquired in the pursuit of vitamin research that the layman is apt to get the impression that all we have learned in the past few years is how to use vitamins; or worse, he often thinks that a vitamin tablet relieves us of the need for any other attention to the diet. This is unfortunate, for equally great advances have been made in other fields of nutritional research. It is well for us to realize that in the progress of science the knowledge is usually cumulative and supplementary to what has been previously gleaned. In all branches of nutritional science we are advancing rapidly

to an intelligent basis for selection of diet, and many of the advances in the past decade have been on the lines laid down by the pioneers on whose shoulders we are climbing. The vitamin idea has not replaced the calorie but has merely added another factor to influence our choice in the selection of the daily menu.

On February fifteenth of this year (1926) a group of scientists met at dinner in New York to do homage to one of the great American pioneers in nutritional science, Graham Lusk. So far as I know Dr. Lusk has never published a paper in vitamin research. Yet his work and the work of his followers constitute a basis upon which you and I act when we take the family basket to market to obtain our daily food. In fact so complete were the principles of food selection worked out by men like him, that when we had followed them we usually had purchased all the vitamins we needed as well, though neither they nor anyone else knew of the existence of the vitamins when these principles were developed. Let me then briefly show how a field in which Lusk plowed has produced new harvests of value in recent years.

Intermediary Metabolism

A student of nutrition would probably say that Lusk's greatest contributions had been in the field

of "intermediary metabolism". What does that mean? Briefly this. You and I go to the store and purchase meat, vegetables, dairy products, etc., and take them home and eat them. Inside our body these substances ultimately reach our tissues (muscles, nerves, etc.) and are there built into new tissue or burned to provide us heat and the power to do work. They do not, however, reach our tissues as meat and potatoes or as bread and butter. Our digestive tract pulls the swallowed food to pieces and delivers it to the blood in simplified forms. All of the potato starch, bread starch, cane sugar and milk sugar that we eat becomes converted into a simple sugar, such as you find in a can of corn sirup and which we call glucose, before it arrives in our cells. Likewise all our meat, milk and vegetable proteins of whatever type actually enter the cells as simple combinations of organic acid and ammonia. Our fats are likewise split into glycerin and fatty acids before delivery to the cells. Our tissues then have just these few building stones out of which to make fires or to build body and we have been intensely curious to learn how they use these substances in accomplishing the result. It is in contributing to this knowledge (intermediary metabolism) that the name of Lusk has come particularly to mean progress, for obviously if we know how a thing is used in a machine we can better run the machine, better select the sources

of the building materials for the machine and better repair it when something goes wrong.

Metabolism of Fat

Let us then take one single example from the contributions in this field and see what has happened to it in recent years. When the fat which we eat has reached our tissues as an acid composed of the elements carbon, hydrogen and oxygen, we burn it to carbon dioxid and water if we are normal. If, however, our diet lacks sources from which glucose can be produced by digestion (starches and sugars), our power to burn fat completely is stopped and we accumulate partially burned fat in our tissues in the form of acids, called collectively *acetone bodies*. Glucose then is necessary in order that the fat may be burned to harmless CO_2 and water, just as the aid of kerosene may in some cases be needed to burn completely a stubborn wood. Lusk himself has put this fact with a poetic turn, by saying that "fats burn in the flame of the carbohydrate."

But suppose we do have smoky fat fires and accumulate partially burned products in the tissues. What harm do they do? These *acetone* or *ketone* bodies are actually thrown out of the tissues into the blood for removal. Then trouble begins. Our blood is nicely adjusted to a certain

alkalinity¹ and if we change this alkalinity to acidity the change immediately results in distress, followed quickly by unconsciousness and death unless the tendency toward acidity is removed. It is this partially burned fat that produces the coma and death of diabetes. We call this condition "ketosis" or acidosis occasioned by acetone bodies.

Insulin

Very recently (1923) F. G. Banting of Toronto startled the world by isolating a substance called Insulin. To most people the word suggests simply a cure for diabetes. How did this come about? What is insulin? How does it act? Banting's great contribution was the separation of this substance in pure form so that we could use it. The basis for his search rests, however, on the work which told us about fat metabolism. It is generally known that the diabetic cannot utilize more than a very small amount of the sugar required by normal people. Evidently, then, the diabetic cannot burn his fat as you and I can. It was learned some years ago that in an organ which the butcher calls the "belly sweetbread" and which physiologists know as the *pancreas*, there is a substance formed which in some way changes the glucose of our blood so that it

¹ See p. 110.

will be absorbed from the blood by the tissues and take part in the combustion of fat. This substance is called insulin. If we have it, not only can we eat starches and sugars, but what is more important, we can use them in our combustion operations. Lacking this principle, the diabetic may eat the carbohydrates, may digest them to glucose, but he cannot use the glucose as he should. What Banting did was to take insulin from the pancreases of animals and enable us to inject it into the diabetic and thus give him what his own manufacturing organ could not produce in satisfactory quantity. The experiments that led to these results were performed chiefly on dogs. (See pages 93-94)

Ketoses in Children

The knowledge of this mechanism, the outcome of the labors of a great many workers in intermediary metabolism, is of the utmost importance, for now we have means of treating not only diabetes, but other pathological conditions as well, arising from defects in the chain of processes that go to the burning of fat. For example, we often have *ketoses* in children. Like the diabetic, such children are not burning their fat. But the trouble in these cases is often due not to lack of insulin but to insufficient sugar in the diet. Physicians are now curing such ketoses by simply

feeding the child glucose as corn sirup or malted milk, or in some other available form. In certain types of cases insulin is sometimes temporarily used to insure the complete oxidation of fat even though the child's pancreas may be adequate for ordinary needs.

Anemia

There are many other instances of new knowledge in nutrition, entirely outside the field of vitamins, that might be cited. One of the most interesting is some recent work in anemia. It has been generally held that inorganic iron, i. e., iron not bound to some carbon-hydrogen combination, is of little value in restoring our quota of red blood-cells and *hemoglobin*, the substance in the blood-cells that enables them to transport oxygen for us. A recent experiment by Steenbock has opened up a new view of this problem. Knowing that a milk diet alone would produce anemia, Steenbock fed rabbits on milk until they became anemic. He then set out to cure them by suitable dietary combinations. First he gave them inorganic iron in the form of iron oxid. They did not recover. Then he fed them the iron oxid and added cabbage to the diet. Recovery took place whether he used fresh cabbage, dried cabbage or merely an extract of cabbage leaves. This in spite of the fact that the cabbage

alone was ineffective and the iron oxid alone equally so. Why the miracle? Chemists have shown that *hemoglobin*, the iron compound in blood-cells that make them capable of carrying oxygen, contains not only iron but an organic complex to which the iron is attached. Cabbage and other vegetables contain this organic complex though they may contain little iron. This experiment tends to show that we must have both the special carbon-hydrogen combination *and* the iron in the diet if we are to get results. In other words, we are beginning to understand the factors in the chemical synthesis of hemoglobin, and with this knowledge are advancing to intelligent treatment of the disease by proper selection of dietary components.

Some Practical Questions

Many investigations in different branches of science have contributed to a better understanding of nutrition on the theoretical side. Have any practical guiding principles developed from all these experiments? We have attained important guides to the management of diets by consistently asking ourselves the following questions:

What substances in foodstuffs are necessary to keep the organism healthy?

What does the organism do with these substances when it gets them?

What effects are produced by eliminating or reducing the supply of necessary factors present in the raw product?

Some Practical Answers

The replies to these questions may be briefly summarized.

1. Since the body runs a furnace for the production of heat and activity, foods must contribute fuel. To determine satisfactorily how much fuel is necessary we must be able to measure both the fuel needs of the individual and the fuel contribution made by a given weight of any food-stuff. The unit of measurement for this purpose is the calorie. To say that the body "needs calories" is then a statement of a need that will always exist; calories cannot be replaced by any other factor in dietary supply.²

2. Everyone is familiar with the essence of the old German epigram, "Man ist was man isst", one is what he eats. The truth of this statement

²The calorie is not the name of a substance but of a unit of measurement like hour or foot-pound. The calorie is the amount of heat that is used up in raising the temperature of a litre of water (a little more than a quart) one degree on the centigrade scale. Strictly speaking, we do not eat calories; we eat foods which yield energy in the course of the chemical changes they undergo in the body. This energy varies, for a given quantity of food, with its chemical composition. This is what is meant when we say a pound of fat furnishes more calories than a pound of meat.

is at best partial. Professor William J. Gies has reversed this by stating "We eat what we eat because we are what we are". Chemical analysis of the human body shows that it is composed of chemical elements in various combinations. Water is one of these combinations, lime salts, iron compounds, phosphorus compounds, are others. The *purely organic combinations*, that is, the groups of chemical elements that are in nature found only in bodies of plants and animals, can be divided into three main classes according to their characteristic reactions. They are known by the group names of *proteins*, *carbohydrates* and *fats*. Not only must we provide these *nutrients* in the diet, but the body needs a definite amount of each; below this minimum we cannot safely go. The second requirement in nutrition then is that our foods shall contain the proper kinds and amounts of nutrients.

3. Many of these nutrients are, however, complex bodies made up of various members, just as a chain may consist of various kinds of links. When the body uses these chains it separates out the links and each link serves a given function. To provide chains then is not enough, we must see that these chains have the proper kind of links. We may need calcium in the body, but we find that the operation of cooking may convert the calcium in the food into a form that cannot pass through the walls of the gut into the blood, and is there-

fore useless. Having made sure that our daily food purchase includes the calories and nutrients (1 and 2) we must then impose a third basis of selection, viz., that the nutrients be of the proper *quality*.

4. Hay meets all the above requirements for the cow. We cannot use it. Why? Simply because our machinery will not take the hay to pieces and deliver to the blood the chemical combinations needed for the tissue uses. We say the hay is indigestible by human beings. Foods then must be *digestible* by the organism that is using them.

5. Twenty years ago these needs outlined above constituted the basis of food selection. To-day we know that all these needs may be met and yet the animal die. We have learned that we must also have in our diet *vitamins*. Today we recognize five kinds of these factors to which we give as names the letters A,B,C,D,E or the descriptive names anti-xerophthalmic,³ anti-neuritic, anti-scorbutic, anti-rachitic, anti-sterility, which tell what they guard against. We have no reason to believe that the list is complete, but we must have these in our daily food intake, or suffer more or less serious consequences.

6. Most of our food must be cooked, for what

³ Deficiency of vitamin A in the diet results in a dry inflammation of the eye; of vitamin B in an inflammation of the nerves; of vitamin C, in scurvy; of vitamin D in rickets; and of vitamin E in sterility.

we eat will function better if it is palatable, and many sources of nutriment can become available only through the cook's art.

7. It may be practicable to prepare a combination of substances that would be palatable, digestible, well balanced and containing all the essentials of the complete diet, and yet be unsuitable for maintaining health, since our digestive system, especially the intestines, can be maintained in normal working condition only if the muscles of the food tube are properly exercised by kneading or churning material from time to time. For these reasons our food must contain a substantial proportion of fiber or other inert substance which takes no part in the actual nutrition of the living tissues.

Dietary Slogans

The above is a very brief statement of what we need to know in order to purchase satisfactory twenty-four hour diet. There are no bad foods, but there is often bad selection of combinations of foods from failure to apply these guides. Nearly everybody is probably familiar with the slogans devised to help the layman in food selection, disregarding those that have a purely commercial purpose: "A quart of milk a day for every child"; "Eat more whole grain cereals"; McCollum's suggestion that we include one green

vegetable and milk in every day's dietary, and so on. Each is based on a partial application of the seven principles cited. Why, for example, is milk exalted? Because with the exception of calories and of vitamins C, D, and E and iron, it supplies almost all the factors listed and is our best known source of calcium or lime. Why has whole wheat a greater food value than white flour? As a source of calories whole wheat is almost equal to the white flour, but it excels in the combination of proteins, in supplying iron and other mineral salts, and in containing vitamin B. It lacks, however, necessary calcium and the other four vitamins.

Applying these principles to food selection must bear far-reaching consequences. They are already affecting foodstuff advertising fundamentally. I wish to close this discussion with a general suggestion. The science of nutrition does not classify food in the categories good and bad, but recognizes that nature has supplied very few complete foods and a great many varieties of incomplete foods. Our diet must be complete, but this does not mean that I must abjure white flour and eat only whole wheat, or that because I need green vegetables, meat is not a valuable foodstuff. It simply means that if I have chosen rolls, meat and oranges for to-day's menu, I must supplement these with other purchases that will supply the nutrient factors which these

lack in the amounts required by the body. Obviously the power to do this lies in knowledge as to what meat, oranges and rolls contribute and as to what they lack; and so with other articles offered in the markets. Also we see that if we include in our diet a few articles that are fairly complete in the required factors, such as milk, green vegetables, whole cereals, we can follow our appetites more safely in the purchase of the rest of the meals.

Instinct is a very poor guide to food selection and is not a substitute for intelligence. During the past quarter century, we have made great progress in getting facts about nutrition, largely by using experimental methods. If we can in the next quarter century make as much progress in teaching parents the principles of food selection, the health of the race will be tremendously improved.

THE ADJUSTMENTS AND UNITY
OF THE ORGANISM

William A. White, A.M., M.D.

CHAPTER V

THE ADJUSTMENTS AND UNITY OF THE ORGANISM

The study of the mind was largely absent from the curriculum of medicine in past years. The interests of the doctor were directed almost exclusively to the body. Yet what good is the body unless it is possessed of a mind that has the capacity to make a place for itself and to find satisfaction in its activities and in the activities of the body? If we have a body and even if we can keep it well, if it is nothing but that and no more, we have not gone very far. Medicine and hygiene that can merely keep the body in order have not benefited enough from efforts in correlated fields of science. It is important for us to apply the scientific methods of study to the problem of the adjustments and unity of the organism from the point of view of the mind.

I wish briefly to sketch the underlying principles of the structure of the organism.

The One-Celled Organism

Let us start with an organism that consists of but a single cell. We find in this nothing that

corresponds to the many and diverse structures found in higher organisms, as for example, organisms like ourselves. It is a little bit of something in which the living functions are present—it moves; it takes food; it responds to disturbances; it excretes wastes; it reproduces—but we get the impression that it is a more or less homogeneous mass and we search in vain for definite organs. Yet there are minute structures present which, while they correspond to nothing in higher living things, may have functions of which we know nothing.

These one-celled bits of living matter are capable of nourishing themselves by enveloping bits of suitable material and incorporating these within their own substance. The material thus taken in and liquefied diffuses through the jelly of the organism from part to part without being carried along any definite route or system of transportation.

Throughout we find what seems to be a lack of organization in simpler cells. Not only does the material taken in spread out in every direction without following definite structural paths, but the same seems to be true also for incoming waves of energy. These pass from part to part of the cell and do not seem to follow a definite structural path.

If we throw a stone into a pond, waves spread out in all directions and gradually disappear.

If we throw a second stone in at the same point before all the waves have disappeared, the new waves will also die out. If we imagine, however, a pool of jelly-like material into which a stone is

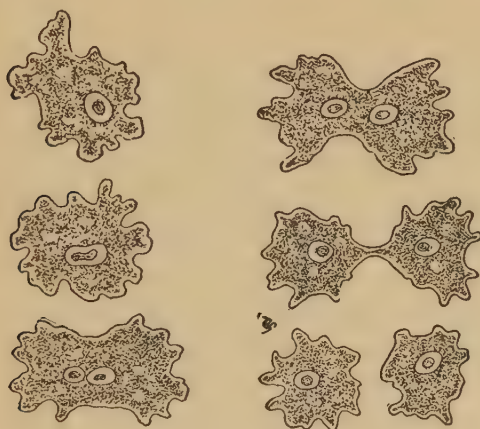


FIG. V. A ONE-CELLED ANIMAL, AMEBA *

The amoeba has no definite shape, but moves about, pushing its jellylike mass now in one direction, now in another. This animal has no organs corresponding to a mouth, but takes in food at any point upon the body surface. It has no organs corresponding to lungs or gills, but breathes over the entire surface. It has no structure corresponding to sense organs or nerves, yet the whole surface is sensitive to a great variety of disturbances or stimulations. It has no structures corresponding to muscles, but the whole mass of jelly is contractile. The amoeba has no special reproductive organs, but after reaching full growth the cell divides into two parts, each of which is as complete as the other, and both the same as the mother-cell, except for size.

* From *Biology and Human Life*, by Benjamin C. Gruenberg; Ginn & Co.

thrown, we may conceive that a second set of waves and a third might result in a permanent structure by the time the jelly has set.

Tendency Toward Definite Structure

There is a tendency in living matter for the paths of energy to become permanent; or there is a tendency for the energy to travel along lines previously traveled. In the same way, there is in living matter a tendency toward structuralization. There are vague beginnings of definite tracts which ultimately become permanent. These energy waves tend to become permanent and energy travels most easily along the paths that have been previously laid down.

Time does not suffice to trace that tendency by citing examples all the way up to the human organism. It is enough for our purpose to emphasize that in this tendency is the beginning of what I like to call the *structuralization of function*. In other words, the energy of the stimulus tends more and more to bring out, along the path of its discharge, definite tracts which are ultimately rendered distinct structures. Just as the water from a heavy rain storm washes over the side hills and gradually channels out for itself little canals in the soil and ultimately channels out the river bed, so these discharges of energy channel out for themselves in this semi-gelatinous protoplasmic

mass pathways that, as time goes on, become deeper and deeper until they become permanently organized. This permanent organization is transmitted and becomes ultimately a part of the structure of the organism.

Plans of Symmetry

Now, to take a little jump, we find that these organisms, very soon after they pass this simple stage, tend to become organized along certain plans, so that we have organisms built up in patterns of symmetry.

We have, to begin with, the anterior-posterior, or the frontal type of symmetry, the differentiation of the front end of the organism from the rear end of the organism. And we have a symmetry which is from side to side, a bilateral symmetry. Finally we have the symmetry from the surface downward, that is, the dorso-ventral symmetry.

So we very soon find that these little organisms have a head end and a tail end, and a right and a left, and an upper and a lower.

Dynamic Gradients

Experiments have been worked out in the laboratories whereby it has been shown that the energy in the organism is highest at the point

where the stimulus is received—at the head end for example. And, as we go backward from the head end, the energy is less and less intense. This tapering of the energy intensity is called the *dynamic gradient*. So it can be shown by experiments that the paths are from the front to the rear end of the organism; and the surfaces above and below act in the same way. That is shown rather interestingly by the capacity with which the organism absorbs certain substances. Vials of various substances can be placed in the water so as to diffuse the material slowly, and it then appears that an organism which is capable of absorbing any of these substances absorbs more rapidly at that portion of the gradient which is most active and where the energy is at the highest tension.

"Mind"

There are two or three things to which I wish to call your attention from this simple account of organisms in general. The first is that the head end of the organism appears early in the evolution of animal life, and that there are two types of distribution of energy which this organism shows. One is the distribution of energy along these dynamic gradients and the other is the transportation of chemical substances throughout the organism along paths that develop with the organization of these gradients.

So we see that the little single-celled organisms already have a head in effect, if not in structure, and many who are working in the field believe it is proper to say that they have the beginning of what we call "mind". It is not, of course, a mind that is comparable to what you and I know in our personal experience as mind, but a mind that is just as comparable to the mind that we possess as the physical make-up of that simple organism is comparable to the infinitely complex physical make-up of our own body.

The Unity of the Organism

From the point of view of a general definition the mind is nothing more nor less than the final representation of the function of the organism as a whole. When we talk about a man's liver or his heart, or his kidney, we are talking about parts of his organism and we are interested in physiology. But the minute we ask this question, What is the *man* doing? or in other words, as soon as we incorporate in our query about the organism words that indicate that we are dealing with the whole individual, then we are necessarily speaking in psychological language. So, when we ask, What is the monocellular organism doing? we are speaking in psychological language. Speaking from the point of view of bodily make-up, we find then that these unicellular organisms

represent in their very beginnings the simplest forms of the structures that through millions of years of evolution ultimately result in the complex organisms with which we are familiar. In the same way, we think that we find here also the beginnings of those psychological types of reaction, wonderfully simple as compared with the psychological types we see in human beings.

Two Types of Organization

We may start by saying, therefore, that there are two types of organization. The first type, familiar in all the higher organisms, is that in which there are definite structural paths for the transmission of energy, as well as definite structural paths for the transportation of materials. In the other type, represented by the simplest living things, transmission of energy and transportation of materials go on without such definite structural channels. The unity of the organism, which is effected by what we called the "mind", is just as characteristic of life on the lowest levels as it is of life on the highest levels. The mind is as old as the *soma*, or body.

Now, we cannot expect to understand the mind in any other way, or by any less severe discipline, than we understand the body. We must study its history as it has developed through the ages in the same way as we study the history and de-

velopment of the body. It is the way of science by which we have come to learn so much about the body; and it is the same way that we are coming to learn so much about the mind.

The Elementary Nervous System

To leave the chemical method of transportation out of the picture for the moment, let us trace some of the outstanding features of the development of the nervous system, to see how this scheme of development follows along. If we go up a little higher in the biological scale, we come to certain many-celled organisms. Compared to the one-celled organisms, multi-cellular organisms are rather complex; but still these are very simple when compared to the vertebrate type. We find a type of nervous system which is called a *net-work* nervous system. On the surface of these organisms having such a nervous system we find a point that is modified somewhat for the reception of a stimulus. In a remote part of the body we find a point that is modified for reacting to that stimulus.

For instance, the tendrils or tentacles of the sea-cucumber receive the stimulus and then there is a muscle fiber surrounding the bases of the tendrils, so that these react and contract when the stimulus is received. Connecting the so-called receptor and effector organs, we find a little fiber of

nerve running along. These nerve fibers are distributed in what appears almost a haphazard way. They look almost as if these lines of force of which I have just spoken had, as a matter of fact, been laid down in structureless protoplasm, because they are not grouped in strands like electric wires and copper cables such as are found

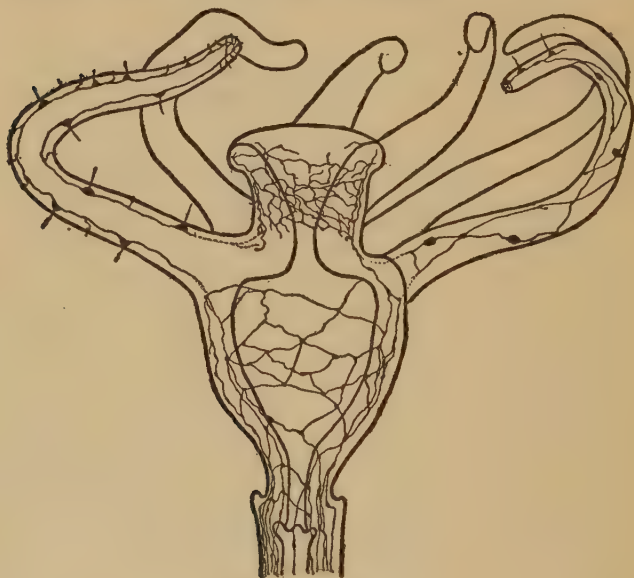


FIG. VI. A NETWORK NERVOUS SYSTEM

In animals related to the jelly fish, sea-anemone and corals, there are sensitive spots upon the surface, connected by means of nerves to the muscles in the body wall, and in the tentacles. The stimulation of a given spot on the surface always brings about the same response in the form of a movement.—From Wolff, after C. Judson Herrick, *Neurological Foundations of Animal Behavior*; Henry Holt and Co.

in a modern building. They are scattered here and there, but are always connected with a receptive organ, and there is an acting organ at the other end. This is called the net type of nervous system because the nerve elements are distributed like the fibers of a net.

The interesting thing here is that the action or behavior of the organism is very definitely determined. When the stimulus falls upon a certain part of the organism, it communicates, so to speak, the result of that stimulus to the distant point at which the other end of the nerve is connected, and a reaction follows with almost absolute mathematical accuracy. The organism is therefore, to a certain extent, entirely dependent for its life and existence upon the sort of stimulus it receives. Such organisms, for example, do not go out in search of food; they attach themselves to a rock and wait for food to float along. When food touches them, their tentacles contract and they drag the food into the mouth. They go on living in a rather casual and automatic sort of way.

The Central Nervous System

When we proceed still further up the scale, we find that nerve fibers begin to be gathered in definite pathways, bound together in strands more like an electric cable. These strands run in defi-

nite parts of the organism. You will find in the anatomy of an ordinary earthworm, for example, a cable running along each side of the middle of the earthworm on the ventral side of the food tube, and connected across at each segment until the double chain gets to the head. And there you will find a great accumulation of nervous matter. Here still we probably have a very determ-



FIG. VII. THE LADDER TYPE OF NERVOUS SYSTEM

Two series of nerve centers are arranged the whole length of the animal, one pair in each segment, or "ring." The nerve centers in each segment are connected with one another, and with all the other organs in the segment. The centers in each series are connected with one another by means of nerves running lengthwise. The largest group of nerve cells, making up the "brain," are in front of the mouth, and the main connections between the brain and the rest of the "ladder" form a loop or ring around the gullet.—From Hilton, after C. Judson Herrick, *Neurological Foundations of Animal Behavior*; Henry Holt and Co.

inistic type of nervous system. It does not leave the organism much chance for variation in its conduct.

There is an interesting story connected with that type of nervous system which I want to tell you because, while it may not be true, and it may be, it shows the wonderful things that nature perhaps can do.

This nervous system goes up on either side

with connecting strands across, until it gets to the front. Then there is a ring or circle of nerve fibres surrounding the esophagus or gullet. Now this gullet is a part of the food tube, food passes through it on the way from the mouth to the stomach. The ring of nerve fibers around the gullet is typical for all the segmented worms and for all the arthropoda, or jointed-leg animals, a large group that includes the insects, spiders, and crustaceans (lobsters, crabs, etc.).

An eminent biologist in England spent many years trying to find out how this type of nervous system finally got to be the type of nervous system that you and I have, the system which belongs to the vertebrate or back-boned animals, and is characteristic of animals that have the higher types of mind. He developed this theory which I will outline very shortly. I do not know whether it is so or not, because it has never been verified. It would take a lifetime to verify it and no one has as yet shown a tendency to devote the major part of his life to see if it checks up.

Brain versus Food

These segmented organisms were dependent upon food, as all of us are; and the food became scarcer and scarcer so that they had to develop brains in order to develop methods to find food when it was scarce. This type of organism that

I am talking about belongs down at the level of the spider. You know how the spider has probably solved that problem for himself. He has quite a large brain of this type, but the brain has increased so much that there is but very little room through that circle of nervous tissue for food to pass. As he is no longer capable of eating solid food, there being no room for it to get through, he catches flies and sucks the fluid from their bodies and that fluid is his food.

The point reached by the spider then is this—he had to have brains, but the more brains he got the more they shut down on his food-tube, and if he developed too much brains he would starve to death; on the other hand, if he did not get food he would also starve to death, and he could not get food without developing brains. That is a pretty tough position to be in and, as Professor W. H. Gaskell said, right at this point in the history of evolution, living organisms, so to speak, had to decide whether in the future life would be a matter of belly or a matter of brains. One or the other had to give way.

New Type of Nervous System

Now an extraordinary thing happened. I can't tell you the story because I don't know it, and I don't know who does know it. A new intestinal tract was developed outside of the nervous sys-

tem. The old gastro-intestinal tract runs right up between the bars of nervous fiber, but the central nervous system of vertebrates is developed on the back or dorsal side and the gastro-intestinal tract lies ventrally. There are some very interesting things to show that that happened. It isn't

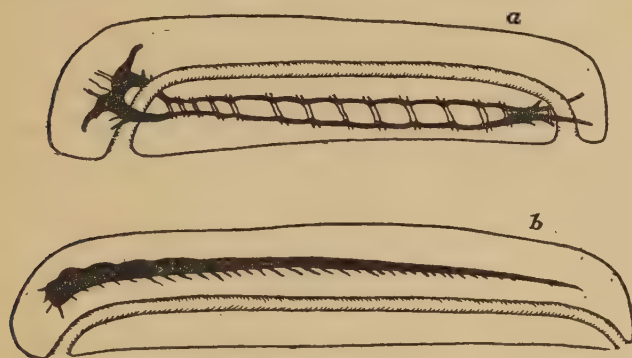


FIG. VIII. TWO TYPES OF NERVOUS SYSTEM

In the segmented animals (*a*) the central nervous system, of the ladder type, lies between the food tube and the ventral or belly surface. In the back-boned animals (*b*) the central nervous system lies on the dorsal side of the food tube.

generally realized that the brain and the spinal cord are hollow organs. There are great big ventricles or cavities in the brain, a long ventricle running down the spinal cord. That is supposed to be the relic of the old gastro-intestinal tract that was abandoned.

At the base of the brain, there is a little gland

known as the *pituitary gland* [See page 93] of which you may have heard. Right through the center of that pituitary gland there runs a little channel and that is the remains of the old esophagus of our friend the spider. It is there today and that pituitary gland is made up of two distinct parts: one of these comes, during the development of the embryo, from the upper portion of the esophagus; and the other is derived from the nervous system. So we have with us today the trace of this old conduit and we have to be thankful that the conflict between belly and brains was decided in favor of brains.

The Brain

That type of nervous system which the segmented animals have, because of its resemblance to a ladder, is called the *step-ladder* nervous system. Some of these invertebrata, as soon as they got rid of the incubus of this gullet passing through the center of the brain, developed a different type of nervous system which was no longer subject to the old limitations; and the principal element in that nervous system was the head end or the brain. In all the long history of the development of the nervous system, there is evidence all along the line of the gradually increasing size and increasing complexity of this brain.

We were able, by discarding the old gastro-

intestinal canal, and by developing the nervous system that was so located as not to be subject to those old limitations, to develop a nervous system which was capable of indefinite size. And while the brains of lower vertebrates like birds and fish, are perfectly smooth, we find that the brains of man and the higher mammals are thrown into corrugations like the radiators you see in an ordinary house-heating system. The effect of this wrinkling is that there is a much greater amount of surface in the same limited space. If the gray matter covering the corrugations of the brains were spread out it would occupy a surface of about three or four square feet, and that is all compressed into the skull.

The Cerebrum

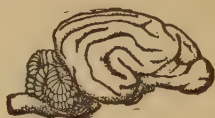
The portion of the brain that has to do with the highest functions has developed more rapidly than any other, and that highest portion of the brain consists of the hemispheres of the cerebrum. These have become so large that now as you look down upon the brain from above, you can see nothing else. They spread over everything else. You look down upon the brain of a fish and you will find all the parts serially related; if you look down upon the brain of a man, you will see nothing but cerebral hemispheres.

In the course of evolution, therefore, an organ

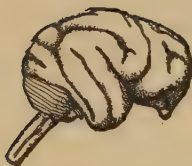
has been brought into existence that has apparently untold capacities for development. We are inclined to believe that the kidney, liver, spleen and the rest of the internal organs, even



Pigeon



Dog



Monkey



Man

FIG. IX. BRAINS OF VERTEBRATES*

On comparing the lower vertebrates, fish, batrachians and reptiles, with the higher ones, birds and mammals, we find a progressive increase in the absolute as well as in the relative size of the fore-brain or cerebrum, with a corresponding decrease in the relative size of the mid-brain. The same progressive change is found on comparing birds with the mammals and the different families of mammals among one another. There is also to be noticed an increasing amount of convolution or wrinkling of the brain surface. The greater cerebrum area in the higher animals corresponds to greater numbers of association neurons and so to greater variety of response to stimulation or to greater intelligence.

* From *Elementary Biology*, by Benjamin C. Gruenberg; Ginn & Co.

the spinal cord itself, and the more simple portions of the nervous system, have probably reached for all practical purposes the limits of their development. But in this brain, the cerebral hemispheres, so far as we can see, may continue to increase not only in size, but in complexity.

The Cortex of the Brain

We already have in these cerebral hemispheres a thin covering called the cortex, which is only a Latin name for bark. This cortex is but two or three millimeters in thickness, less than an eighth of an inch. And we already have in that two or three millimeters of coverage, an enormous number of nerve centers, each one of them infinitely more complex than the single monocellular organism we started with.

I don't suppose that the billions of cortical cells can be connected up in every combination that is mathematically possible; but with billions of cells, the number of combinations is for all practical purposes quite unlimited. We evidently have here an organ which is capable of indefinite broadening, indefinite development, indefinite elaboration.

We have other organs that develop to such a point of complexity or perfection that we do not require of them any further development. After all, we are no longer living in a civilization where

brawn and muscle and bone are of so much importance. Thanks to our old friend the spider, we are living in a civilization in which brains are of the greatest consequence, and all we need from the rest of the organs of our body is to maintain sufficiently these brains so that they can do their work.

Multiple Discharge

Now another element of enormous significance has entered into the situation. In speaking of the net type of nervous system, I said that there was a single fiber connecting a receptor organ with an effector organ, and that therefore any stimulus discharged to an absolute finality. It was delivered at a certain point and there was no possibility of sidetrack.

Now in the higher nervous systems of higher mammals, this cortex has developed a different kind of scheme. It has developed what we call the *synaptic* type of nervous system. When a stimulus starts, as when I pick up my watch for instance, I have certain feelings in the ends of my fingers; the stimulus starts traveling up the nerves of my arm until it gets to my cortex. It does not result in a single, absolute, determinate response. I can put the watch down, turn it over this way, or throw it across the room (if I wanted to, but I don't) or I could do a thousand

different things with that watch. What is the structural foundation that makes it possible to do any one of a thousand things as the result of a single stimulus?



FIG. X. THE REFLEX ARC

The sensitive spots or surfaces of an animal are in direct connection with a nerve cell (*a*) which brings the effect of a stimulation or disturbance towards the central nervous system (for example, the spinal cord or the brain). This nerve cell may connect directly with one (*b*) carrying a stimulation to a muscle (*m*) or to a gland (*g*). In other cases, one or more nerve cells (*c*) may be interposed between the receptor cell (*a*) and the effector nerve (*b*). The nerve cells do not appear to be in direct contact with one another, but the very delicate branches of one nerve come close to the corresponding branches of another, constituting the so-called synapse (*s*), across which the discharge is supposed to jump from one nerve cell to the next. A given receptor may have synaptic connections with two or more effectors. Similarly, a given gland or muscle may be aroused to action by a variety of stimulations.

The nerve that travels up my arm to my brain does not travel directly to the muscles, it stops in the spinal cord, gives off a large number of little fibers and these fibers in turn run toward innumerable other fibers without being structurally connected with any of them. It runs close to these, almost touching them but not quite. That place where fibrils from different nerve cells come close together but do not quite touch is known as the *synapse*. This gap breaks the current. And this stimulus that travels up my arm comes to a certain point and then instead of being absolutely determined in a single, specific direction, it can go in any one of innumerable directions according to which path is finally chosen. There is thus an interval between the reception of the stimulus and its starting off on one of these many spinal-cord pathways, the delay which we know as the time factor in the traveling of nervous impulses. We believe that in this interval are born thought, doubt, choice and all of those functions which we associate with the higher activities of the mind.

So much for evolution of certain types of adjustable mechanisms. We have seen that our body is made up in this sort of way. Now what are the capacities within it for adjustment?

Reserve Capacity

In the first place every organ we have in our body is present in quantity far in excess of what

we need for ordinary purposes. You are familiar, for example, with machines of one sort and another. We have some three hundred and fifty horse-power dynamos in our power house. We know perfectly well that those dynamos will run efficiently if they have to deliver four hundred and fifty horse power, but they are rated at three hundred and fifty horse-power. In a similar way every organ in our body is furnished in sufficient quantity so that it can deliver twice as much at least, and sometimes more than that, as its rated capacity for service, so to speak.

For instance, in the case of the kidneys, you know that it is possible for a surgeon to remove one kidney and leave the other to do the work for the whole body perfectly well. It may grow a little larger in doing it, but it has the capacity for growing larger. We say then that it is *hypertrophied*, or overgrown, because of the additional demand. So we may get along very well with one kidney, but we have two, as a sort of factor of safety.

All of us would have a terrible time with our hearts if they weren't able to stand the additional loads of one sort and another which we put upon them. Whenever we exert ourselves we may put a double demand upon our hearts. Similarly, every organ in the body is capable of adjustment within a wide range, depending upon the demands that are made upon it.

Function Precedes Structure

There is one other aspect of the organism which is still more important from the point of view of adjustment, and that is the mind. I have already indicated, by implication rather than directly, that mind was largely a function that had not yet become structuralized. It uses the structure, to be sure, that it finds at hand and ready to use, but it is still largely unstructuralized.

Some philosopher has said that matter is mind hidebound by habit. We might paraphrase that and say that the structures of our bodies originally were mental and have gradually become bodily functions. It may seem at first to be transposing what we ordinarily think of as "cause" and "effect" to say that the function leads to the formation of structure, instead of saying that structures produce or result in functions. The fact remains, however, that in the development of an individual organism the embryo absorbs and assimilates food before it has any special digestive organs, its cells use oxygen and discharge the products of oxidation before it has any special breathing organs, and so on. In the same way, as we have already seen, the essential life functions appear in the lowest types of plants and animals, long before there are any definite structural instruments for any specific function. As the functions have been performed over and over again, the organism

has established a certain type of response which has survival value.

Survival Values

Fish may swim into water that is too hot for them, and in which they would perish, but when a fish brought up in warm water starts toward the Arctic zone, it will turn back when it gets to the colder waters. It keeps where it can continue to live. That reflex turning back is a function which has been laid down in the structure of the organism. It is a life-saving function, a function that has *survival value*.

Whether or not I talk for five minutes more, or what I say within reasonable limitations, would not have survival value. I might say some things, perhaps, which would result in my disintegration by an enraged audience, but I am not liable to try that. Ordinarily the things that I say would mean very little so far as concerns whether I live or die within the next two years. They have not survival value. Therefore, there is no reason why they should be laid down in structure, because structure determines a definite and fixed type of reaction for all time. Moreover, we cannot lay down functions in structure until we have tried them out over and over again, millions of times and through thousands of years, and are sure that we are right.

So it came about that what we call the mind remains function that is not a structure, and therefore is very adaptable. Mind is like the fluid of the monocellular organisms, the fluid protoplasm, or the still water in the pond. It can be thrown into waves in any direction, from a given stimulus. That is probably not an accurate analogy, but speaking within certain limits, it is helpful. The mind represents in large part the fluid or unfixed capacity for readjustment which we all carry along with us. It gives survival values in circumstances that would find fixed responses fatal.

It might be helpful to add, at this point, some few more definite and familiar types of reaction to illustrate further the general principles outlined thus far.

*Automatic Adjustive Movements*¹

When my hand touches something very hot, two results follow immediately: I feel pain, and I withdraw my hand. As an intelligent being I have come to realize that pain is decidedly disagreeable, something to avoid, if possible. I therefore put two and two together and reason something like this: Heat causes pain, pain is to be avoided, therefore I withdraw from the hot point. Some of us will explain what happens in a somewhat different way. We may say: Burn-

¹ Prepared by the Editor.

ing is injurious, therefore Nature, or Providence, has endowed us with a means of recognizing it as something to get away from, namely, the pain that it causes. Yet the facts disclosed by careful observation and experiments do not agree with this reasoning, plausible as it seems.

In the first place, when you touch something hot, you withdraw your hand before there is time for you to realize that you have felt pain. In the same way, you shut your eyes *after* the flashlight has already finished its work of taking a picture, when you no longer need protection from the excessive glare. If you successfully dodge something flying toward your head, you do so before you can really be aware of the danger. In other words the nervous process that results in the feeling of pain, or in the awareness of danger (in certain cases) comes on a side branch from the point at which the adjustive action is determined.

Adjustments of this type are automatic. Whatever consciousness may be connected with them is largely in the nature of a by-product, and not at all a guide or cause of the action.

Nervous Basis of Reflexes and Instincts ²

The feeding habits of many animals illustrate remarkable automatic adjustments. When you go

² Prepared by the Editor.

fishing, your luck depends in part on having the right bait, in part on the fish seeing your bait. The rest is already laid down by fate in the structure of the nervous system of the fish. A sense impression upon the *receptor* or receiving organ of the animal (in this case the eye of the fish) sets up a nervous process ending in an *effector* or acting organ (in this case the muscles working the mouth of the fish). The stimulus always sets up more or less appropriate responses: the adjustment, so far as it goes, is automatic, and depends upon the structure and properties of the nervous system (see Fig. 10, p. 161).

A frog will snap at a fly, or at a moving worm; it will not eat a dead fly or worm, or other suitable food, *at rest*. The frog will snap at a bit of moving bait, whether it is suitable food, or only a bit of worthless wool. The movement for food-getting is set up by a particular kind of stimulus, although in this case the movements are not adjustive or appropriate. In general, however, the frog and the fish, like the rest of animal creation, may be excused for their occasional mistakes by the fact that particular kinds of stimuli correspond only to situations to which the animals are naturally adapted: the responses are normally adjustive.

Among human beings there are present at birth many sets of stimulus-response nerve connections. But there is present also the capacity to form new

connections. The new-born child begins to suck when something touches his lips, or his cheeks near his lips. Normally this touch is related to the child's food supply; but the response is the same whether the stimulus comes from the nipple of the mother's breast, or somebody's finger, or the nose of the Teddy-bear. Again, normally the sucking begins only when the mouth is touched. Mothers have a way of making peculiar sounds when they handle their babies; and we may notice that after a few days a baby's mouth begins to work before anything touches him, merely when the mother makes those sounds. We may say that the child has "learned" to know his mother's voice, or that he "associates" this sound with the approach of his food. We may also describe what happens by saying that the normal response to a certain touch has been modified or conditioned, it has been shifted to a different stimulus—in this case, sound.

Ordinarily, dogs and human beings do not have a natural nerve connection that makes the mouth water at the sound of a bell; but dogs and human beings and other animals can be so conditioned that they will respond as to the sight and smell of food on hearing the dinner bell. This fact, then, that our responses can become attached to new kinds of stimuli is very important in the making of adjustments to the complex world in which we live. It means that almost any stimulus can be

made to serve for almost any reaction. This is how it comes about that printed or spoken words, facial expressions and gestures, flags and signals, colors and smells, and otherwise meaningless sense impressions of all sorts do actually tell us what is happening around us, do actually make us respond more or less appropriately to the thousands of things that are important to us. It is by discovering significance, by establishing meanings, and by associating these meanings with suitable actions, that we adjust ourselves as well as we do to the demands of life.

*Nervous Basis of Unity*³

If the nervous system is the basis of our adjustments to the complex environment, it is also the basis for the unification³ of all that is going on within the complex organism. An imaginary example will illustrate the importance of this function. Since we have the possibility of receiving a large number of stimulations at the same time, some from close by and others from a great distance, we have also the possibility of responding, at any one moment, to several different stimuli. As I walk along the street, one stimulus may tempt me to turn into a place for some refreshment; the sight of an automobile coming along may suggest that I start to cross the street be-

³ Prepared by the Editor.

fore it gets too close; I catch a snatch of conversation that should make me turn in another direction to satisfy my curiosity; a discomfort which I locate in my jaw suggests that I ought to go to the dentist before I do anything else; a sudden noise makes me turn my head and I see a crowd gathering beyond the next corner to the right, and I feel the impulse to join the crowd. Obviously, I cannot do all the things I am impelled to do, nor many of them. Neither is it feasible to make a schedule and check off the relative value or importance of each desire and temptation and impulse and aversion. Moment by moment I go ahead, doing now one kind of thing, now another, often indeed several things simultaneously, but not often flying in several directions at once in response to stimuli that do actually come from several directions. If I am in fairly good health, physically and mentally, I act as a unit, as a whole organism, directing my movements to more or less definite ends.

From the earliest days of infancy each one of us has somehow been acquiring the trick of sticking to one thing or a few things at a time, of attending to some stimuli and ignoring others, of always letting certain impulses take precedence over others. All this we have done because our nervous system is what it is; and thus has the organism acquired its unity and so does it express it; thus has a miscellaneous bundle of more or

less conflicting response-tendencies become an individual, an integrated person.

Automatic Mind

Now there are certain parts of our organism which represent stages that are intermediate between this fluid quality of mind and definitely laid down structures. I refer particularly to the lower, older portions of the nervous system which control the viscera, the internal organs and the so-called endocrine glands that we hear so much about today (see page 92 ff.). The function of those glands is to secrete certain chemical substances which travel to various parts of the body through the blood and the blood vessels, and so we still maintain today the old transportation type of adjustment which we had when we were mon-cellular organisms. This transportative type of adjustment represents organically what has not been laid down in definitive structures.

Reproduction

There is one very interesting correlation to which we have come from all this study. The original experiments were made by Professor Charles M. Child, of the University of Chicago, in defining his theory of the dynamic gradient

method of organization, with flat worms. These organisms are only little things, about a quarter of an inch long, but they are very easy to experi-

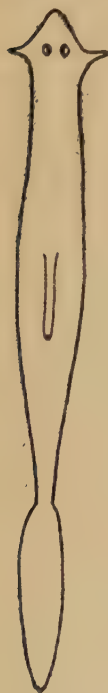
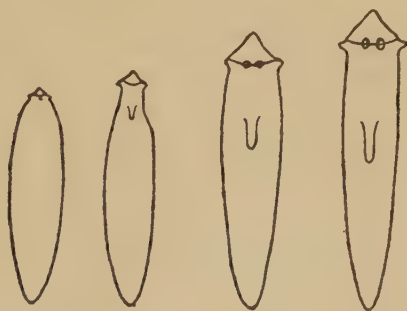


FIG. XI. REPRODUCTION IN A FLATWORM

When the individual has grown to a certain size, the front end moves away, leaving the hind end attached to a rock. This abandoned portion, incomplete in structure, gradually grows distinct organs and soon becomes a complete individual.—After C. M. Child, *Physiological Foundations of Behavior*; Henry Holt and Co.



ment with and he found in studying these worms a very interesting method of reproduction. These worms grow, and they grow to a certain definite size. They crawl along the ground by a sort of wavy wriggle. When they get to a certain

size, what happens? The rear end of the worm sticks to the stone upon which it is crawling and the forward end of the worm keeps on crawling and the strand between gets thinner and thinner and finally the forward end of the worm breaks off and leaves the rear end attached to the stone. Then the rear end immediately develops a head and starts off on an existence of its own. That is the way reproduction takes place. Let us see what has happened.

By dynamic gradients, you will remember, we mean that the greatest amount of energy is at the head end and the energy dwindles off toward the tail. When the worm gets so big that the energy at the head end cannot travel the whole distance, it peters out, it no longer can control any more worm, and the worm that is not controlled is left behind and starts out on its own independent existence.

That is exactly what happens in human society. You form an organization. You have two or three hundred members and by and by you get so you can't keep it together. One head cannot send out enough energy to control adequately every part. The various factions in the organization become more and more insistent, they develop their own leaders and break away from the parent organization. You are all familiar with this process.

Malignant Growths

Every organism has a dynamic gradient. That is dependent upon the fact that the controlling force at the head end is not sufficient to affect all parts of the body equally. When some irritation develops locally, it is like an insistent leader springing up in a group and adding enough energy so that the energy set up in that little group is greater than the energy received from the original controlling force. The local region may start off on an excursion of its own and develop an organization of its own. And that organization has an objective out of harmony with the main organization, the larger organization, and it tends to destroy it. That is one reason why these malignant formations, like cancer, develop late in life.

Regressive Structures

Another interesting thing I wish to call to your attention is that whenever an organism undertakes to reproduce itself, the first thing that happens is that this highly complex organization begins to break down and the organism drops back to the simple, undifferentiated condition in which it started off on life's journey. The hind end of the worm, for example, starts without a head, a tail, or any other distinct structure. It starts

simply as a little broken-off end of the worm, and then it begins a process of differentiation—head and eyes and then intestines and other organs begin to develop. When it reproduces in turn all that differentiation breaks down and it all comes back to simplicity.

That is exactly what happens with us, and other higher animals, except in a somewhat different way. The germ-cells (sperms and eggs) which we carry in our bodies are undifferentiated cells that have been separated out in the earliest stages of individual existence. When the embryo is progressively setting aside layers of cells that become respectively skin and muscles and bones and glands, and so on, groups of cells remain simple in structure, undifferentiated. These cells become eventually reproductive cells.

Two Groups of Instincts

The organism manifests two types of instincts. First is the race-preservative instinct, or as it is sometimes called, the sex instinct, or the instinct of reproduction, the life instinct, the instinct for life and immortality. The germ plasm that we all carry is handed on from generation to generation. [See page 52 ff.]. We may die individually, but the germ plasm goes on forever. It is millions of years old.

Then there is the group of so-called ego in-

instincts, the instincts that make the individual develop along his individualistic lines and make each individual different from every other individual. These instincts are the instincts that make for differentiation. When we die, it isn't our germ plasm that dies, it is the structure that we have built upon the germ plasm that dies.

We might say that these undifferentiated cells that carry the germ plasms are the oldest part and these individual characteristics that we have acquired in the course of our lifetime are the youngest part of us, and the things that we have acquired last, in the declining years of life, are the youngest of all. The undifferentiated cells really represent our oldest part. That has very interesting implications. It means that the death of the individual is a part of the dedifferentiation process which, from the point of view of the race, means constant rejuvenation. The death of the individual is as important for the life of the race, as is the germ plasm itself.

Individual and Race

These individual differentiations are experiments that are thrown out like the branches of a tree. Ultimately they die off, having probably communicated something of the results of their experiment to the parent stem but having left with the parent stem nothing that interferes with survival.

Take for example the differences in race. Presumably differences of races are just like these individual differences that have been built up as side issues along these ever forward-going streams of germ plasm. We have questions raised from time to time, as to the supposed inferiority of certain races. We always like to think that whatever race we belong to is better than any other race, and so we like to think that the other fellow isn't as good as we are.⁴ Naturally, he is infer-

⁴In ordinary uncritical thinking, race distinctions present themselves either as the obvious superficial differences in color, hair, facial features, quality of voice, or in some subtle and mysterious "mental" differences that elude description except as higher or lower, better or worse. That there are objective, physiological differences is strikingly revealed by comparative studies of the reaction of different races to specific diseases. Generally speaking, dark-skinned races are more susceptible to measles than are the whites. In European countries and America this disease is commonly looked upon as a minor ailment of childhood, whereas its introduction among more "primitive" people results in a high proportion of fatalities. A fact of this kind must not, however, be taken to indicate any superiority or inferiority on the part of either race. The blacks of Africa are much less susceptible to the destructive effects of hookworm than the white races. That there is a race factor involved and not merely a question of living conditions is shown by the experience of the South Sea Islanders with diseases introduced from Europe. In the Marquesan Islands there was a population of exceptionally fine physique, a healthy, happy and intelligent people, living the "simple life" without the strains and distractions of our high-pressure civilization. On several of the islands these people have been almost entirely destroyed in the course of three generations by tuberculosis, syphilis and gonorrhea, imported for the most part from France. The air, the sunshine, and the food are as good as ever; the susceptibility of the natives to these diseases is much greater than that of the white races. Ed.

ior. But when we say that, we do not quite bear all of these things in mind. Perhaps the so-called inferior races are closer to the fundamentals than the so-called superior races from this point of view. Perhaps they are in a better position to pick up the modifications of present-day life which are of value and significance.

It is worth while to keep in mind these two possibilities of the two great instincts, one *Eros*, making for life, and one *Thanatos*, making for death. The death instinct is the one that we follow as inevitably as the moth follows the flame because it means the aggrandizement of our own personality. We have, whether we will or not, ultimately to die, and by dying to contribute our individual share to the rejuvenation of the race, to the instinct of *Eros*.

PREVENTING SICKNESS AND
PROLONGING LIFE

C.-E. A. Winslow, D.P.H.

CHAPTER VI

PREVENTING SICKNESS AND PROLONGING LIFE

The title "Preventing Sickness and Prolonging Life" is a little too ambitious. I would like in the time at our disposal merely to take one particular group of diseases, and to review the steps by which we have gained a relatively high degree of control over them. The group I have chosen is that of the epidemic diseases, the plagues, pestilences and fevers.

First of all we should try to divest our minds of what we already know about these diseases and look at them for a moment as they appeared to our forefathers and even to the best medical scientists a very short time—fifty to one hundred years—ago.

A man is run over by an automobile truck and killed. There is nothing mysterious about that. The mystery is that it does not happen oftener. If a person gets old, and his bodily machine wears out, and finally he drops over with heart disease, that, again, is not particularly mysterious. This other group of diseases, of which I am speaking,

presents us with very much stranger phenomena.

Here is a man who gets up in the morning perfectly well and fit; gradually he begins to feel a little dull and heavy and sleepy; the wheels of his vital engine drive slowly; he begins to realize that he is feeling flushed and hot. Soon he becomes weaker and weaker; he thinks he will go home and get to bed; and perhaps the next morning he is tossing about in delirium, so weak that he is unable to lift his arm.

It is a strange thing that has happened to that man. Something has come out of the unknown and stricken him down suddenly. When you add the fact that this sort of disease does not come singly, but is likely to spread through a community, from one person to another, just as fire spreads through the underbrush in a forest, you have something which may well command the astonishment of the human race.

There have been in medical history essentially three explanations of this sort of phenomenon.

Demonism

The first, which was almost universally believed until the time of the Greeks, was the explanation that such attacks of contagious disease were due to spirits. This was the demonic theory of disease. To primitive man it was a natural sort of deduction, that some spirit, instinct with

almost human malignity, had seized upon the person and made him sick.

In many medieval pictures of the plague you will see the Angel of the Lord at the top of the picture emptying the vials of wrath upon the heads of the people. Of course, if that was the cause of epidemic diseases there was only one thing to do, and that was somehow to propitiate the spirit, to buy it off by sacrifice, or perhaps to frighten it off, by invoking some other more powerful spirit to defend you against it. And hence we have the charms and incantations to protect against disease which have come, as you know, right down to our own day.

I remember very well that in Connecticut during the influenza epidemic of 1918 all the stocks of camphor in all the drug stores were sold out because everybody was buying camphor, and sewing it up in little bags and hanging it around their necks to ward off influenza. Only within the past month we have read in the newspapers of a very curious episode in France that takes us right back to the Middle Ages. Near Paris a priest was beaten almost to death by a group of people who believed that he had brought sickness to them by magic spells.¹ These people came from near Bordeaux, and they thought that the priest had bewitched birds and caused them as they flew south to carry the disease and make the people

¹ In February, 1926.

sick. Here is the demonic idea of disease in its most primitive and typical form.

Miasmas

In almost every phase of human thought we owe a great deal to the Greeks, not because their views were right, for they were often almost as wrong as the views they superseded; but because they had this one tremendous advantage: the Greek theory was always founded upon the idea of natural law.

The particular view advanced by the Greeks might be wrong, and generally was wrong, because they had not observed nature long enough to draw correct deductions, but it assumed that there was a natural law that you could understand. It was an attempt at a rational theory, which meant that it could live and grow and improve because any theory that is based on natural law, however wrong it may be, can be corrected, and will by its very nature be corrected by subsequent study and experimentation.

Of course, if you believe that disease is due to spirits, there is nothing more to do, except to bow down before it. But the Greeks looked at the matter otherwise. The Greek theory of disease was essentially a theory of *miasma*, the theory of atmospheric contamination. When the plague came to Athens, they thought there was some-

thing in the atmosphere that caused the disease; and they believed that the corruption of the atmosphere in its turn was closely related to the influence of the stars. This may seem to you just as magical and just as mystical a theory as the theory of demons. But we must be very patient and careful in criticizing these theories of early days. The Greeks did not believe this theory of the influence of the stars to be a theory of magic. They thought it was a matter of natural law; they thought they observed it; they thought they noted by experimentation that the stars did control human events. They were following the scientific method, but they lacked the scientific spirit which doubts, hesitates, waits and tests again and again. And they lacked the instruments of observation and the instruments of precision which have revolutionized modern science.

They saw that under a certain conjunction of the planets Alexander was born, and they concluded that those stars influenced the birth of Alexander. We use the same method in the scientific laboratory except that we do not form our conclusions upon one instance. We test it and try it and gradually and slowly perfect our knowledge of the truth.

The Greek theory, then, was the theory of miasma, of atmospheric influences, and we still have it with us today in the fear which many people

entertain of the spread of disease by bad smells, by sewer gas, and so on. This theory exists to-day in the over-emphasis on fumigation. Fumigation has its place in certain diseases and under certain conditions, but progressive health departments have now given up fumigation after the ordinary contagious diseases because it does not accomplish anything important.

Hippocrates, the father of medicine, thought that he conquered the plague of Athens by building fires in the streets, so that this fire could consume the harmful elements in the atmosphere. This theory persisted down to very recent times, and curiously enough it was for a long time the official doctrine of medicine.

Contagions

Slowly, however, people began to realize that in diseases like smallpox and plague there was such a thing as contagion, or transmission by direct or indirect contact with the person afflicted. All during the Middle Ages there was a gradually growing emphasis on this idea of contagion as opposed to the official doctrine of miasma. The doctor still believed, however, that the diseases originated in miasma, in decomposing organic matter, in some corruption of the atmosphere. Later they had to acknowledge that the diseases

spread from person to person, but the leading authorities held as late as the early eighties of the last century, that diseases like typhoid fever could also be generated by decaying organic matter.

Infections

Then, about sixty years ago, all this began to change, and the basis was at last laid for real knowledge of the causation of communicable diseases. It came in a curious way, and a very indirect way, which I want to outline to you because it shows how science grows, and how far-reaching may be the effects of a line of investigation which at first sight seems to hold nothing of moment for mankind.

In Paris in the fifties of the last century, there was a young French chemist at work on the relation between the form of crystals and their chemical composition. That is a subject which certainly seems to have exceedingly little practical importance or significance. But he had found that there were certain chemical substances known as tartrates (salts of tartaric acid), which were alike and yet differed in certain definite ways. He found that not only did they differ chemically, but that the crystals had different forms when studied under the microscope.

Fermentation

In the course of these studies he became interested in the subject of fermentation, because some of these tartrates and other similar substances were formed normally in fermenting liquids. Fermentation was a problem which had always been puzzling and curious; and as many people had perceived, it was a little like the problem of communicable diseases.

It had even been noted that fermentation, like communicable disease, spreads sometimes from one subject to another; that, for example, a mouldy apple would help to spoil other apples. It was also noticed that fermentation, like communicable disease, ran a definite course; that in the transformation of a barrel of apple juice first into a sweet, sugary fluid, cider, and then into an acid liquid, vinegar, each fermentation ran a definite course, and when this course was over that particular change could not happen again, just as each communicable disease—measles or typhoid fever or scarlet fever—runs its particular course, leaving the subject immune from that disease for some time thereafter.

Fermentation at this time, like communicable disease, was supposed to be due to the oxygen in the air. But this young French chemist doubted this, because he found certain substances in these fermenting flasks which he thought must

have been built up by some living thing. He thought they were new substances, and so he came to the conclusion that fermentation was a vital process (see pp. 97-98).

When he looked at the fermenting liquids under the microscope, he saw that they were swarming with microscopic life—tiny little rods and balls and spirals. Most people had thought that these microbes were the *result* of the fermentation. Pasteur—for it was he—thought they were the *cause* of the fermentation, and carried on a set of experiments in which he demonstrated that this was true.

Spontaneous Generation

He showed that if he took a fermenting liquid, say a solution or an infusion of meat in water, and heated it to destroy all germ life, and then sealed it up, it would not spoil. But it took many years before he established his point. Other men carried out experiments which they thought showed that Pasteur's contention was not true; they believed that microbes were spontaneously generated in decomposing liquids. Finally, step by step, Pasteur proved that it was not the air itself but something in the air which caused the fermentation, and that this something in the air was made up of minute living things. He went up on the Alpine glaciers with some of his flasks

that had been heated to destroy germ life, and broke them open and let the air in. Very few of them spoiled at all, showing that in the pure air of the high mountains there were none or few of these germs of decay.

Microbes

About 1856, he showed definitely and clearly (1) that fermentation was due to microbes, and (2) that microbes are *not* spontaneously generated. This was the germ theory of fermentation, that one microbe comes from another just as an oak comes from an acorn, and that each specific kind of fermentation is due to a specific kind of microbe.

Pasteur was then called to the University of Lille, his theory still far from being accepted.

The great national wine industry of France had been suffering severely because of the spoiling of the wines from some unknown cause, and he now took up the study of the diseases of wine. He found microbes in the wine, and he showed how the diseases of wine could be cured by heating the wine to destroy the invading microbes. Thus originated the process we call *Pasteurization*.

Silkworm Sickness

In 1865 a new call came to him, again a call

for service in behalf of the industries of his country.

In the south of France there are districts supported entirely by the cultivation of silkworms. The worms are brought up in great sheds on wooden frames covered with mulberry leaves. Things were going badly with the silkworm industry; the worms were turning sick and black, and dying.

Pasteur was sent for because he knew how to use the microscope and because he had solved the troubles of the wine industry. He went down there into the silkworm district and examined these worms, and in the bodies of the sick worms he found little microscopic bodies, living things which looked like the things he had found in the spoiled wine. It was a long time before he convinced himself that this was really a germ disease, but in 1867, after two years' work, he finally demonstrated that this disease of the silkworms was due to microbes.

Disease in Mammals

Meanwhile his early theories and studies of fermentation had suggested to others that the situation was analogous with human diseases. Lister in London applied this theory in 1867 to the terrible wound diseases, and developed the methods of modern surgery. Koch in Germany

began to apply the same theory in the study of other diseases, and it was he, and not Pasteur, who in 1876 for the first time demonstrated that anthrax or splenic fever, a disease of the higher animals, was really due to a microbe. With infinite patience, infinite care, he studied the blood of the animals dead of the disease, and in it he found a microbe shaped like a particular kind of little moving rod.

Koch's Criteria

Others before him had shown that the various diseases could be transmitted from one animal to another by inoculating the blood, but that was not proof of the germ theory of disease. In order to make the proof definite and clear, what must you do? You must take this microbe out of the blood and cultivate it, grow it pure, away from the blood, grow it generation after generation in the laboratory, and then put the microbes from the last culture back into a new animal and produce the disease. This Koch accomplished, and it was the crucial test that clinched and completed the proof of the germ origin of disease, suggested by Pasteur. It was not an easy thing to do. Remember that microbes are so small that you cannot take one out in your hand or with a pair of forceps and plant it somewhere. The experiments require ingenious technique.

Pure Cultures of Germs

Shortly after this Koch discovered—and it was one of the most important steps in the development of bacteriology—an ingenious method of getting pure cultures of bacteria. He would take a drop of the blood of an animal dead of anthrax, for instance, and instead of transferring it to another liquid culture medium, as Pasteur had done, he mixed it with a soft jelly. Then he poured this into a dish and let it cool, and the jelly would harden so that each one of those germs was imprisoned at a certain point in the jelly.

Then, if the jelly had food substances in it suitable for germs, each one of the imprisoned germs would begin to grow and multiply and divide and you would have a little colony that you could see, as big as the head of a pin or a ten-cent piece. By this method Koch made it possible to secure pure cultures of these germs, and he cultivated them generation after generation, and finally put them back into animals to reproduce themselves—and to reproduce the original disease.

Importance of Technical Progress

The whole science of modern bacteriology depends on three ingenious bits of machinery.

First, the improvements in the microscope that were made about 1838: the discovery that by combining two particular kinds of glass it was possible to overcome the old difficulties that left the microscope an inefficient instrument. Second, the discovery, in the seventies, that you could bring out under the microscope the structure of tissues and of microbes and other things by the use of aniline dyes, for certain chemical stains would stain certain parts of the tissue or certain kinds of microbes red or blue or green so that you could see them clearly under the microscope. And third, this discovery of the solid-jelly culture of microbes.

These three little mechanical improvements made it possible to see the bacteria, to distinguish them by dyeing, and to cultivate them so that you had a single, tiny microbe all by itself, with which you could experiment.

Tuberculosis

Finally in 1882, by this same sort of patient, complete technique, Koch discovered the germ of tuberculosis. This was the first important human disease shown to be due to a specific microbe, and from this demonstration of the relation of the tubercle bacillus to the disease of tuberculosis in 1882, dates the opening of the golden age in bacteriology.

What was the value of all this? What difference did it make?

Isolation in Disease

Let me remind you of a few things that this developing science of bacteriology made possible. In the first place, it made it possible to carry out scientifically what people had tried to do before unscientifically, the isolation of cases of disease.

One of the first methods used, not much by the Greeks, but in very early times by the Hebrews, described in the books of Leviticus and Deuteronomy, was isolation—isolate your sick people and separate them from the rest, and prevent the germs of disease from spreading.

Now the really important thing is not the sickness but the germ, and just as soon as we had these new methods of Pasteur and Koch, we discovered that a disease germ might stay in a man's throat or other parts of his body for days and weeks after he was well, so that our isolation had been incomplete and unsatisfactory. We would isolate the patient while he was actually sick, but long after that he might be spreading disease germs about him, like "Typhoid Mary", the famous New York cook, who caused eight different epidemics of typhoid fever. The bacteriological culture method made it possible to pick out those people who were continuing to spread the germs of disease.

Carriers of Disease Germs

This led to the discovery of a still more dangerous type of individual, the *carrier*. This is a person who, while not necessarily having had the disease himself, cultivates the germs in his nose or throat or bowels, and while resisting it himself through some particular property of the blood or tissues, spreads the germs to everyone with whom he comes in contact. The bacteriological methods made it possible to detect the carrier and make quarantine effective.

There are some diseases, like infantile paralysis and epidemic influenza, of which we still do not know the germ. We are still as helpless with regard to these diseases as we were with regard to typhoid and tuberculosis before the days of Pasteur and Koch, because we either do not know the germ, as in influenza, or we have no convenient and easy means of identifying the carriers, as in the case of infantile paralysis. Our whole practice of control depends on the ability to find the carrier of a disease and to determine when he ceases to be dangerous.

Vehicles of Infection

The knowledge of these germs has made it possible to study the vehicles by which they are transmitted. Our whole point of view on this

matter has been changed by bacteriological studies. People used to think that disease germs would spread through the air. They used to think that dust played an important part in spreading disease, and some people think so now; that objects, books and toys, and things that have been handled, perhaps months or years before, were common means of the spread of disease. We know better now, because we can study the lives of disease germs outside the body, and we have learned that they die out very rapidly in earth or water or dust, or when they are dried.

Parasites

Disease germs are parasites adapted to life in the human body. It is instructive to remember that the word "parasite" was coined not for microbes, but for human beings. It was an honorable word in the beginning. It meant companion, mess-mate, "buddy". Gradually it began to be associated with a contemptible person, and a parasite came to mean a man who was a hanger-on in a rich man's house, generally displayed in later Greek drama as crippled, bald or decrepit.

The disease germ is a parasite, and, becoming adapted to life in the human body, he has, like the human parasite, lost his ability to gain an honest living independently. He dies very rapidly outside the body. We know now that it is a direct

transfer from person to person we have to fear, direct spread by contact with milk, water, food or insects.

Insect Disease Carriers

One of the most interesting chapters in the history of medicine is that which concerns one group of diseases, the insect-borne diseases. Diseases are spread either by direct contact, by food and drink, or by insects, and the group of insect-borne diseases is one of peculiar interest and importance.

The first disease to be definitely worked out as insect-borne was a disease of cattle, not of men, the discovery being made in this country by Dr. Theobald Smith. This disease was known as Texas fever, and it occurred particularly when southern cattle were brought up to the north or northern cattle were brought down to the south. It occurred too, most mysteriously, when northern cattle were driven on the fields previously occupied by southern cattle.

Theobald Smith finally worked out the problem by a process of logical exclusion, followed by careful experimentation. With year after year of study, he found that this disease was spread by the bite of a tick, and that southern cattle were immune because they had recovered from the disease in their early years. These immune cattle carried on their bodies the ticks which bore

the germs of the Texas fever, and these ticks dropped off and later spread to other cattle that came over the same grounds.

Malaria

In 1898 came the discovery of the first important human disease spread by an insect, malaria. The name malaria means "bad air". It was preëminently the bad-air disease. It prevailed near swamps and low-lying regions, it occurred when people dug up the soil, and it was supposed that this disease above all others was due to some kind of emanation from decaying matter in the soil.

A large part of this observation is correct. It is true that malaria does occur in marshy places, and where the soil is upturned, but this is not through any effect of miasma. It was an English army surgeon in India, Ronald Ross, who took the first step toward solving the malaria problem. He had become interested in the theory that malaria was caused by mosquitoes, a few years after Theobald Smith's work on Texas fever in cattle.

He began studies on human malaria but was unable to finish them. He started out with a very poor equipment, for while he was a good doctor he knew nothing about mosquitoes and lost a good deal of time. He really had the right mosquito,

but he did not even know its name; he called it the Dapple-winged mosquito. He got only suggestive evidence; and then he was called away to another station where there was no human malaria.

Ross continued there with the study of the malaria of birds. Birds suffer from a disease very similar to human malaria, and one caused by a very similar parasite. In 1898, Ross succeeded in showing that bird malaria was due to the bite of a particular mosquito, that the germ was thus spread from one bird to another. Then Grassi, an Italian, took up the question, and luckily and boldly went ahead and proved that the same group of mosquitoes with which Ross had worked was the agent which transmitted malaria in man. Then that whole problem was solved.

We now know why malaria occurred in marshy lands and where the soil was dug up. These conditions meant the presence of stagnant water, the mosquito's breeding-place.

Yellow Fever

This was in 1898, the year in which the American Army of Occupation went to Havana. Havana had some malaria; it had a good deal of typhoid fever, and a good deal of smallpox; but above all it had a peculiar and deadly disease known as yellow fever, a disease which was particularly associated with tropical America, and

which for a hundred years had spread almost every year to some part of the United States.

It broke out again and again in New York, and all over the country, introduced on ships from the south. Nobody knew how it was caused. There was a general idea that it was carried in the goods, in the bales of cotton, and so on. The cargoes of ships from infected ports were all held up and disinfected in the most elaborate way at a tremendous cost, and, as we know now, without any practical results. The basic knowledge was not there. They were right in those days to act on the best guess they could make, and they had no means of knowing the truth. They did their best, but they were wrong.

When our army of occupation went to Havana in 1898, Colonel George Edward Waring, the man who organized the White Wings and cleaned up New York City, was sent down to clean up Havana. This he did, and stopped typhoid fever. He vaccinated the people and stopped smallpox. But the yellow fever went on and on, and nobody knew what to do about it. We always are helpless in fighting a disease until the secret of the mode of transmission has been discovered.

A Systematic Search

In 1900 an Army Commission was sent down to study this problem of yellow fever—Major

Walter Reed, Jesse W. Lazear, James Carroll, all non-immunes, and Aristides Agramonte, a Cuban immune. This was two years after the discovery of the transmission of malaria by mosquitoes. These men naturally began to investigate the mosquito as a possible agent in the spread of yellow fever. The question was, how to find out whether the theory held true. This disease was quite different from many of the other diseases. They could not study it as Theobald Smith had studied Texas fever, because cattle and other experimental animals did not have yellow fever. It was very different from malaria because malaria is generally a comparatively light disease, and because we have a practically certain cure for it in the form of quinine. There was no cure for yellow fever.

Now it was a pretty serious thing to give human beings a disease of this kind, and yet here was the issue at stake. Should this disease go on and ravage America and other parts of the world, or should some individuals be sacrificed by submitting to inoculation, for the good of the rest of the race? The Commission concluded that they were justified in asking for volunteers for this work, but, of course, agreed that the members of the commission should first submit themselves to experimentation.

Human Experiments

Carroll was the first to be taken sick; he recovered, though never fully. Lazear died, the first martyr in this particular expedition. There is hardly a chapter in the history of the control of the insect-borne diseases which is not marked by the story of similar sacrifices. It is one of the finest facts in our national history that there was never lack of volunteers—of men ready to go, not with the crowd into battle, but alone into one of the experimental huts to subject themselves to the risk of this terrible and deadly disease.

In about six months the secret was discovered. It was proved that yellow fever was carried by a mosquito, but a different one from the malaria mosquito. To test the old theory that yellow fever was carried by bedding and clothing, one of the experimental huts was filled with these articles from the hospital for yellow fever at Havana. A group of men slept in it and proved that they could not get yellow fever in that way. You can only get it by the bite of this particular mosquito.

Early in 1901, as a result of this discovery, the commission began its campaign against the yellow fever mosquito. Whereas for the preceding thirty years there had been an average of 750 deaths a year in the City of Havana, there were

18 in 1901 and none in 1902. Yellow fever was stamped out. It was never again introduced, except for a brief period when a visiting ship brought it to the vicinity of the wharves.

Cleaning up the Isthmus

Then came the building of the Panama Canal. The Isthmus of Panama was one of the deadliest spots in all the world, and it was this state of things more than anything else that prevented the French from building the Panama Canal. But we had the advantage of the experience at Havana, and we sent to the Isthmus General William Crawford Gorgas, who had carried on the actual campaign in Havana for mosquito eradication. His superiors did not like it at first. The political commission in charge of the Canal Zone thought the mosquito theory was all nonsense, and recommended to the Secretary of War that Gorgas the theorist be dismissed and some good practical man brought down who would clean things up. The Secretary of War approved this recommendation.

Fortunately, President Roosevelt had a good friend in New York City, a medical man, for whom he sent, saying, "What about this thing?" His friend told him. The up-shot was that Mr. Roosevelt removed the commission and kept General Gorgas. In about two years yellow fever

was wiped out from the Isthmus, and malaria has never been a serious menace since.

So much then for the various lines of investigation, and for the results that have come out of Pasteur's work in the identification of the germs of disease.

Vaccination

Now I want to take up another line of Pasteur's work which has been even more fruitful than the first. We have two lines of defense against the germ diseases: first, keeping the germs out of the body altogether; and second, arming the body itself so that even if the germs get in, it can resist their onslaught.

This has been done for a long time in the case of one disease, smallpox. Edward Jenner, an English country physician, in 1796, by following up what seemed like old wives' tales from the country where he practiced, had discovered that vaccination would protect against smallpox. This happened in an isolated, single disease, and nobody thought of it as a general principle for many diseases, until Pasteur opened up the possibilities.

Chicken Cholera

In 1880 Pasteur was working on chicken cholera. One day he injected some fowls with a

cholera-germ culture that had been left by mistake for some time in the laboratory and had dried up. The fowls got only slightly sick and then recovered. It was obvious that the germ had been weakened, or "attenuated", by being dried up. But later Pasteur injected these same fowls with a virulent culture, a culture that he knew to be good, and he was surprised to find that the animals were immune. This caused him to think.

He wondered if this explained the phenomena of smallpox vaccination. He wondered if it might be a general principle that a weakened germ would protect an animal or a person injected with it against the strong germ, in the same way that, as was well known then, recovery from a communicable disease protects a person for a long time from another attack.

The idea opened up to Pasteur: Would it be possible to produce a weakened culture—he called it a *vaccine*—of other disease germs that would not make the person injected with them sick, but would still stimulate the body to immunity like a real attack of sickness?

Anthrax

He began to try it out. He turned first to splenic fever, which he as well as Koch had already worked on. He found that it could be done. You could not weaken the germ by drying

in this case because of certain peculiar characteristics of the bacteria, but you could weaken it by exposure to particular temperature in combination with oxygen. Thus he was able to produce a vaccine against splenic fever or anthrax.

In 1882 he carried out a dramatic demonstration of the possibility of the use of this vaccine for the protection of cattle. The veterinary surgeons were exceedingly skeptical about it and finally one of them challenged Pasteur to show what he could do. Pasteur was a Frenchman with a taste for drama, and he accepted this challenge.

He said, "I will take so many goats and so many sheep and so many cows, and I will protect them with this vaccine for splenic fever. Then, a week later I will come back, and I will inject all these protected animals and an equal number that have not been protected with the germs of the fever. And we will see what happens." They did see. In due time every animal but two of those who had not been protected by the vaccination was dead or dying; and those that had been protected were all well and strong.

Rabies

Then in 1884 Pasteur applied the same principle to another disease, rabies or hydrophobia, caused by the bite of a mad dog. Pasteur was not a physician but a chemist, and he had never

worked with human beings. He began, as we know, with fermenting liquids, then with silkworms, with cattle and fowls. Now, finally he began to study this terrible disease of rabies, no one knows just why, but partly because of the horror once implanted in him by a person who had been bitten. By another ingenious method he produced a vaccine against rabies, and in 1884 he was forced, almost against his will, to the first treatment of a human case, a boy named Joseph Meister, who was brought up to the Pasteur Institute bitten on the face and who was the first person to be treated with this rabies vaccine.

Beneficial Results

There are two things I want you to notice about all this. In the first place, Louis Pasteur, with his work on these diseases, is unquestionably the greatest benefactor that the race of animal creation has ever had. He has done more through the conquest of splenic fever, rabies, tuberculosis and other animal ills to free the animal creation, the domestic animals of man, from disease than any other man or any other dozen men who ever lived. He sacrificed these animals by the dozens, perhaps by the hundreds, to gain his knowledge, but his work saves every year and every month thousand and hundreds of thousands of animals from suffering and from death.

In the second place this work on splenic fever and rabies was the basis of a whole group of similar discoveries that are applied to human beings today. The first of these was the production of anti-toxin for diphtheria, which came along in the early nineties. Emil Behring, in Koch's laboratory in Berlin, and Roux in Pasteur's laboratory in Paris, were both studying this disease. Behring discovered a method of immunizing an animal against the toxin so that its blood would contain the anti-toxin. Then the flame of knowledge went back to Paris, Roux simplified the method, and in 1894 we had an anti-toxin for diphtheria. Almost at once the death rate from diphtheria dropped from thirty to forty per cent down to ten per cent in Paris and New York and in cities as a whole. In cases treated early, it dropped to nothing.

Then came vaccine for typhoid fever, plague, and a host of other diseases. The latest is scarlet fever, which was worked out about two years ago. It is essentially similar to the anti-toxin of diphtheria and just as miraculous in its effects. But it must be used early. Then the temperature curve drops like a shot, the rash on the skin blanches out, and the whole sickness vanishes.

The Future

For many diseases we still have no vaccine or serum. There is work going on in connection

with tuberculosis, with pneumonia, with influenza, and all those diseases wait for the development of a vaccine in the future. In a host of other diseases this method has given us a new second line of defense which is almost impregnable, and we can get rid of scarlet fever and typhoid fever as causes of death whenever we choose to use the means that are at our disposal.

Those other problems of preventive medicine which concern the constitutional diseases to be worked out through the study of the chemistry of the human body, and those which concern the whole field of mental diseases, are still in the process of solution. But in all of them the method is the same: the patient observation of facts, the testing of hypotheses by experimentation, until safe and trustworthy methods are found of controlling the forces of nature for the uses and purposes of man.

SCIENTIFIC SERVICE AND
PEOPLE'S HEALTH

Haven Emerson, M.D.

CHAPTER VII

SCIENTIFIC SERVICE AND PEOPLE'S HEALTH

There is little popular interest in medical progress unless it promises improvement of the public's health as well as increase of the doctor's knowledge. The medical sciences have been helpful in making life more secure for us, in adding to its average length and at the same time improving its quality for the majority.

Life Expectancy

If you will look back into history, to the time just before Columbus made his great excursion to this side of the world, you will find that the average expectancy of life in Europe was about 18 years; that is, a child when it had reached the age of one year could not be expected, nor could its parents feel any confidence either, that it would live to much more than 18 years of age. At the time of Napoleon, about 125 years ago, the average length of life in Europe was approximately 33 years—a considerable improvement over the time of Columbus. In Lincoln's day,

from about 1840 to 1860, the average expectancy of life in this country according to the experience of Massachusetts was about 40 to 44 years for children who survived the first year.

At present in the United States we enjoy a life expectancy of from 55 to 60 years, according to the city or state we live in. If I am not mistaken, Kansas is the State which in recent years has had the highest expectancy of life—perhaps because in this state there are no slums, no large cities, no crowding. A farming population predominantly and a very favorable kind of stock—those people who survived the Civil War and were in general a resistant and enduring lot of men and women—settled Kansas and have remained there ever since.

City Contrasts

In Pittsburgh we have recorded the shortest expectancy of life among the large cities of this country, and those of you who may have taken part, perhaps, in the industries of Pittsburgh understand the very difficult conditions, partly of climate, partly of industry, partly of housing, and partly of the conditions of employment there, which give Pittsburgh this rather unfavorable expectancy of life as compared to our capital city, Washington, where we find the longest expectancy of life for city dwellers. Washington is a city of wide spaces, separate houses, a favorable and

mild climate on the whole, and suffering from few if any hazards of industry to which we are accustomed in our large manufacturing centers. Washington is a city of residences.

It is evident that within recent times historically there has been a great extension of the expectancy of life, a greater probability of the survival of the child that lives until it is a year old. Yet even now there are many parts of the world where they are no further ahead than they were in the Middle Ages. In India today the average expectancy of life is not over twenty-five years. In Russia before the war, the famine, and the Revolution, the expectancy of life was not over 26 years. However, we may look with envy towards the people of New Zealand who have already attained a degree of health protection which is expressed in a life expectancy of sixty-four years.

If you look about you and think of things as you have been urged to do, that is in a scientific way, you will ask what the facts are, and what the reasons are for these changes in expectancy of life in different communities.

We may note in passing that "public health" is a very poor term, because there is no such thing as a public's health. Public health is the sum of individual healths which we express in terms of great population units—in millions of individual lives.

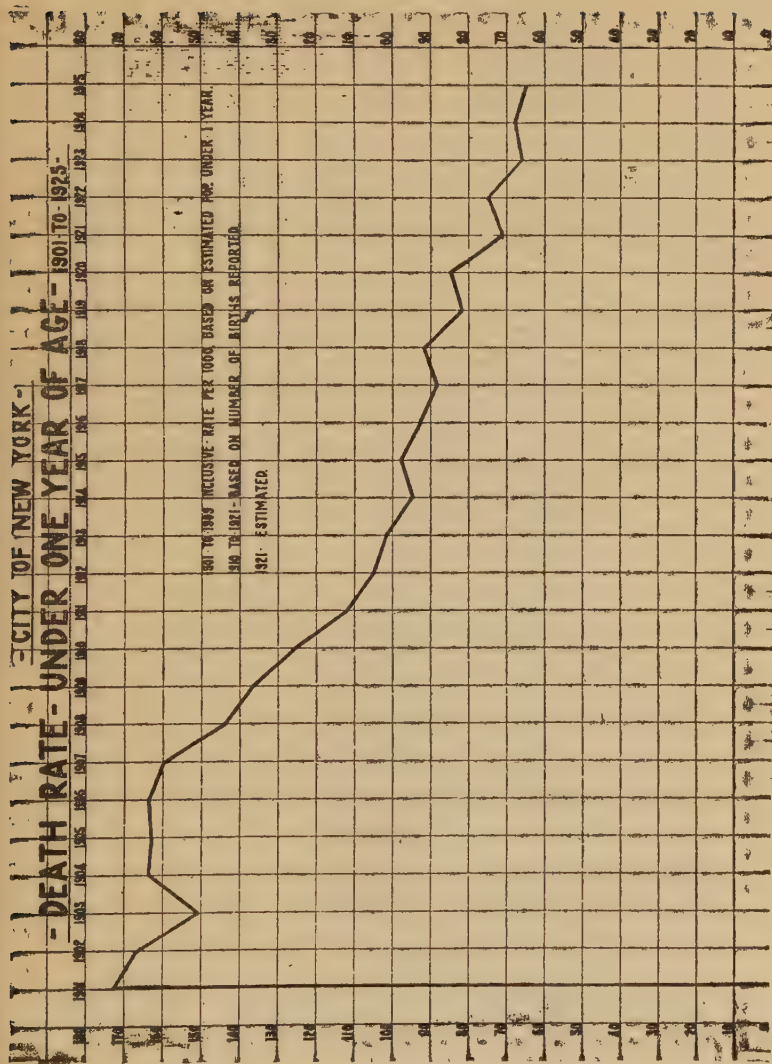
Infant Deaths

It is plain then that the duration of life has been increased. The chief factor in this has been the saving in infant life. A hundred years ago in England one-quarter of all the children who were born alive died by the time they were three and a half years old. In England today this loss of life does not occur until some of the children are 40 years old. Fifty years ago, when I was born in New York City one-quarter of all the babies that were born alive died before they were a year old; that is, 250 out of every thousand. Last year (1925) only 63 out of every thousand died before they were a year old.

By saving the lives of infants so that they may grow up we add to the general total years of life, and thus increase the life expectancy of each of us. We know with a good deal of accuracy that the number of deaths in each thousand of the population, that is the general death rate for people of all age groups, from babyhood to grandparents, has been decreased.

Births and Deaths

Seventy-five years ago more people died in New York than were born each year. New York ate up, with its unhealthful conditions, many people who came to it from other countries in health

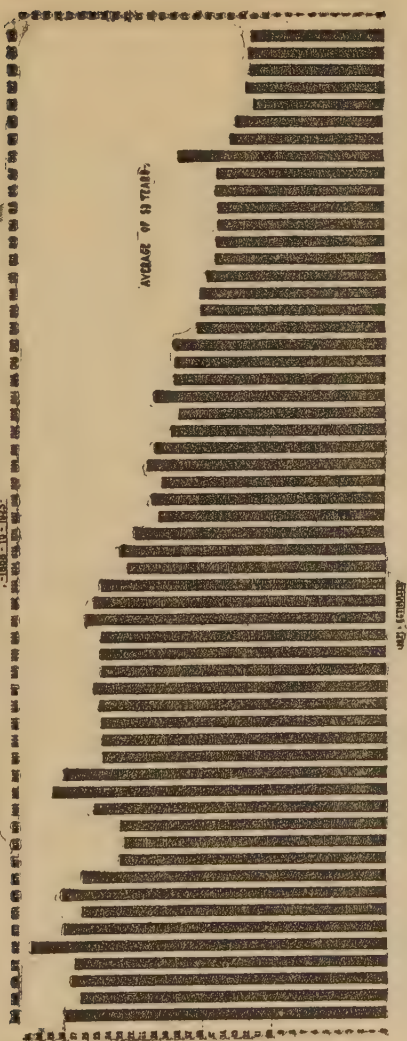


and vigor, and there were more deaths in every thousand of the population each year than there were births. No community, whether city, state, nation or race, can live very long with that kind of a balance sheet. The citizens of New York took notice of that and established the Metropolitan Board of Health, the first in the United States, because there appeared to be no other way in which the forces of science, by sanitation and preventive medicine, could be applied successfully to safeguard the life of the community. The balance was turned in favor of life, and last year a little less than 12 out of every thousand of our city population died and for every thousand 21, almost twice as many, were born.

Importance of the Record

Science is the study of accumulated facts, and we are constantly learning from the facts of previous generations, so that we are very much interested in the study of this record, which shows the death rate of the City of New York from the year 1868, the first year in which we had a complete report of the Metropolitan Board of Health, up to 1925, the last year for which we have a published report. About 70,000 people die each year in New York, and about 130,000 are born, and, as we have seen, instead of a quarter of the new babies dying, only about 63 out of

CITY OF NEW YORK
DEATH RATE - ALL CAUSES - PER 1000 POPULATION
 1868-70-1912



Source: Geo.

the thousand die in the first year. When the death rate was around 30 per thousand, and the birth rate about 26, more people were dying than were born. Today, however, when we get down to a death rate of between 11 and 12, although the birth rate has also fallen, we have a greater natural gain in our population. We also have a great many older people than we used to have, more people living at 45 years of age and over, because they were spared the fatalities of infancy and youth. All this we learn from an exact record of the lives and deaths of the people of our community, and it shows a saving in human life sufficient to account for much of our great growth in population.

The Factors in Lengthening Life

Let us relate the facts given in this study of the population figures of a great city to those presented in the earlier lectures of this series.

You will remember that Dr. Stockard, Professor of Anatomy at Cornell, traced the story of experimental evidence which helped us to understand the nature of inheritance. Among the lessons to be learned from records of many family trees is that if you would be long-lived be careful to pick long-lived parents. No factor is more important in attaining long life. We may be wise and careful in many ways to protect our

own health, but a precious element in the length of life is an inheritance from parents and grandparents who lived sturdily and long. The laws of inheritance are of importance to us in a multitude of ways.

Dr. Stockard also described the bearing of environment upon our development; how darkness and insufficient food or light or air affect the duration of life, the vitality of individuals, their capacity to meet and overcome infection.

He also gave you evidence as to the continuity of living stuff, and described Mendel's law and the visible structure of those little particles in the cells which we speak of as the chromosomes, and which transmit the hereditary factors.

You will recall that Dr. Taylor told how the chemist has contributed from coal tar, from the vegetables, from the slaughter-house, life-giving or life-serving products, and how he has refined and strengthened drugs, and devised new ones, for the prevention and cure of disease.

Then Dr. Eddy reports upon the triumphs over nutritional disease through knowledge of the infinitesimal elements in food, and of the danger to health in the smoke clouds that hang over our cities, and exclude certain parts of the sunlight we need in order to make use of our foods. He also spoke about anemia, about the success in treating diabetes with insulin, and about seven guiding principles in nutrition.

Dr. White then gave you a picture of the fitting of human beings into the complex and very trying conditions of an artificial social existence—how many people break under the strain of trying to adjust themselves to unfavorable surroundings, to unfriendly conditions, to competition, to the fear of poverty. He showed the dependence of the physical processes of life upon our emotional and our mental conditions: that we can hardly have good physical health without good mental and emotional health, that cheerfulness is as necessary as food to our well-being.

Dr. Winslow then reviewed the history of bacteriology, the control of communicable diseases, and the development of artificial immunity in a population by vaccination, as in smallpox and typhoid fever.

Practical Values

Let us test this array of modern and improved information in terms of ourselves. What has all this meant to us, our parents, and to our children? Has anything been done with all these facts of science to make life less hazardous, longer, and better worth living? Certainly, as I have shown you, life is less hazardous for the young than it used to be and there is a greater survival of infancy. Not only has the average age increased,

-CITY OF NEW YORK-
-DEATH RATE- CHILDREN UNDER 5 YEARS OF AGE-
-PER 1000 POPULATION UNDER 5 YEARS ---1877-1925-



but the expectancy of life has been increased for every age.

"But how does the adding up the lives of children help the lives of their parents?" The expectancy of life at the age of one year has been increased. Take then for instance all children living at the age of 5 or 10 or 15, and at each age you will find there has been an increased expectancy of life. Within the last 20 years that increase in expectancy has extended even to the ages of 45 and 55 and 60, so that the people who have reached these later years have a right to expect to live longer than their predecessors did at these same ages.

Many people say that this public health is all foolishness; it saves the children so that they can grow up to die of something else. This is of course quite true. So far as we know everybody dies sooner or later. Consequently, it becomes a question of the time, rather than of the cause of death. Moreover, in saving a healthy child to grow up you prevent a certain amount of sickness in other people: you save lives all along the line, and the wage-earner, the mother or father, and the person past middle life, have had a certain added protection to their lives just as the children have. Taking conditions by and large, for every death prevented or postponed at least ten cases of serious disease or accident have been avoided.

Non-Medical Factors

This progress in public health, this increase in the length of life, is the result of advances in the medical sciences in large part, and also of advance in what we speak of as social justice. Increased wages, decreases in the length of the working day, protection of the worker against the hazards of his trade in shop and factory, less seasonal unemployment have all assisted medical science in giving a greater security to life, by making possible better conditions of living and less dependency.

Science and Sanitation

Let us take two examples of direct contribution to life by sanitary control. Think of our water supply. It is abundant up in the hills; it costs each of us in New York City only three fourths of a cent a day to get the use of 150 gallons of water per capita, but if we allowed that water to come without sanitary protection we should have still, as many other cities have had, typhoid fever, dysentery, and the threat of cholera at times. It took a generation of study to prove that there were chemicals which could be added to water to destroy the typhoid organism and other bacteria in it, and yet cause no harm to the human being who drank it. For fifteen years

and more, all the water that has come into New York has had chlorine added to it. The amount is too small to be tasted, but it is sufficient to make that water entirely free from all the organisms that would cause intestinal disease. In proportion to its cost probably no service of science has saved so many lives as the purification of municipal water supplies.

Safe Milk

Again, we have learned well the food value, the economy, the necessity of safe milk supplies and we use it in large amounts. If we added a pint of milk per day to the diet of everybody in the city we should be improving our nutrition and sparing our pocketbooks. Milk is now brought to New York City from Canada and from 5 or 6 different States, even from 500 miles away, and with each addition to the distance from which we bring it there is an added risk of infection in the milk. In 1914 New York City decided that all milk, except that of "Certified" grade, which represents but two per cent of the supply, must be pasteurized. Milk can be pasteurized in a way to leave it substantially unchanged in food value and in taste and still be free from the risk of spreading typhoid fever, scarlet fever, diphtheria, septic sore throat and a great variety of other infections. Second only, if not of equal im-

portance, to the protection of water supplies, the safeguarding of our city milk has been the cause of most life saving, a triumph of science due to the work of Pasteur.

No one can take care of his own individual water supply or of his milk supply, in a city. We cannot go back to the farm in person and be sure that the dairyman has clean hands, that the cow is clean, and see to it that the milk is kept iced all the way down to the city. These precautions must be secured by the expert supervision of some representative of the public, like the Board of Health.

Averting an Epidemic

In 1889, there came to New York from Hamburg a ship with cholera on board. The people of New York were in a panic; they thought the city would be swept with this plague. It had recently been discovered in the bacteriological laboratories that if you take a specimen of the bowel movement of a person who has had cholera and examine it under the microscope you can tell whether that person is still infectious. A municipal laboratory, the first in the world, was immediately organized; everyone arriving at our Port was examined, and only those free from infection were allowed to land. There was no epidemic. The only thing that stood between

our City, and perhaps the country as a whole, and the kind of epidemic that used to sweep cities in past times was this little knowledge, this little essential fact revealed by science, namely, that under the microscope a certain very minute particle of stained material represented the exact cause of cholera. It cost the City a very small amount for its self-protection. That diagnostic and research laboratory has been continuously in operation ever since, and to this day at the foot of East 16th street it stands as the symbol of science typical of the finest service of which human brains are capable in protecting fellow men.

Routine Laboratory Protection

If you have a bad cough and go to a hospital clinic, they will ask you to spit into a little bottle. The specimen of sputum will be sent to this laboratory to find out whether any tubercle bacilli are in it. If a child has a sore throat, a nurse or doctor wipes a little bit of matter off the tonsil with a cotton swab and sends it to the laboratory to be examined, to find out whether the child has diphtheria or another kind of sore throat. Similarly we are served for typhoid fever, meningitis, hydrophobia and many another infection where life and the safety of households depend upon accuracy and promptness. That is typical of the service of science which now protects us

and our children against the spread of disease, not waiting for an epidemic to come, but catching each case at the very beginning so that it may not spread through ignorance or neglect.

Discarding Useless Measures

It used to be customary to fumigate houses after scarlet fever and diphtheria. People had to burn sulphur or formaldehyde candles. Each year \$50,000 was spent in New York City alone for this process of making a terrible smell in the rooms of those who had died or recently recovered from certain infectious diseases. The studies of the laboratory and field workers discovered, however, that no more secondary cases of sickness developed in homes that were not fumigated than in those that were, and so, as Dr. Winslow pointed out [See page 188] fumigation has been abandoned as useless in controlling bacterial infection, though still of value in destroying insects and vermin which spread disease—fleas, lice, mosquitoes and rats.

More than Changing Fashions

Intelligent men and women, who have not followed the progress of science in the research laboratories, often look upon modern health and curative measures with suspicion. "We cannot

rely upon a doctor's advice because the advice given by physicians ten years ago is no longer considered sound." Doctors do not change their methods according to whims, but as the result of careful evidence based on experience and experiment. Each well supported discovery in laboratory or hospital demands a change in medical practice. There are still people who think a child cannot get whooping cough if it has amber beads around its neck; and seamen in coast towns often think they keep rheumatism away by tying a piece of marlin around their waists. Others still carry rabbits' feet to keep themselves from falling sick. They are perfectly happy and I wouldn't spoil their fun, but theirs is not what we call a scientific way of going about things. They enjoy superstition, tradition, and the habits of their fellows.

One day during the epidemic of infantile paralysis in 1916, I found a man with a go-cart filled with little white cotton bags full of moth balls and cedar shavings, which he was selling among the tenement dwellers to hang around the necks of their children to keep the infection away. It cost him about \$500 and a little while in jail to learn that New York was not living in the Middle Ages, and that a person has no business to fleece his fellow citizens on the basis of their superstitions.

The Physician's Services

Nature cures many an ailment without the aid or benefit of medical opinion or treatment. Even the severe infections such as typhoid fever and pneumonia are not in all cases affected greatly by medical care, under ordinary conditions the patient's recovery being determined more by events preceding infection than upon the particular medicinal treatment in sickness.

We have no certain resources which will save the ten per cent of typhoid patients, and the twenty-five per cent of acute pneumonias who die.

The individual resistance at the time of the infection, and the severity of the infection are more determining factors in recovery than the type of treatment, once the patient has been put to bed. The physician and the nurse see to it that all the forces of nature have their best chance, relying upon rest, gentleness, encouragement, cleanliness, and suitable nourishment to secure recovery in the great group of self-limited diseases. Often all the patient needs is the stimulation that comes from confidence in his physician. A visit from a cheerful neighbor or even a letter of good news will often help him on his course of recovery. A great many sicknesses come simply from fatigue, from discouragement, from insufficient rest at the right time. By rest in bed and suitable nourish-

ment most treatments of sickness are begun—rest in bed to put the person in condition to resist the disease, to give nature and the body a chance. It is not always medicine that helps. It may be that the stomach is overloaded and needs rest from having things put into it. It may be that the eyes and head need rest from looking at things and from attention to anxieties and worries. Rest is the greatest healer. A clean, cool, comfortable bed, gentle care, enough water and not too much food, assure the beginning of recovery for the great mass of patients who come into our hospitals.

Few Specific Cures

Doctors will often tell you that they don't know what the cause of a sickness is, and that they have no cure for it. People who advertise that they have a cure usually have something to sell. There are certain diseases which we can cure, but they are few. We can promise a cure in diphtheria if we catch the patient in the first 24 or 48 hours of the disease. We can cure syphilis by early and persistent treatment with salvarsan and mercury and certain other substances. We can cure malaria with quinine.

The value of the physician after all is not chiefly in offering you a treatment but in being able to tell you whether the ailment you have is a matter of importance, or of no moment.

If you have a lump on your lip, you want to know whether it is a cancer or something else. The physician can tell you. The doctor may not be able to cure the cancer, but he knows that if the lump is of one kind it must be removed, otherwise you will certainly die, but that if it is of another kind you may disregard it, it may go away by itself. In such cases the opinion of the physician is of more value than any particular kind of drug or treatment.

We have no cure for tuberculosis by means of drugs, as we have for malaria or diphtheria. Yet a great many people recover from tuberculosis by changing their way of life and going through a period of rest, proper feeding, quiet, and fresh air, away from the turmoil of shops and stores and streets, so that after a while, by the processes of nature, the body itself will heal the tuberculosis of lung, or bone, joint or gland.

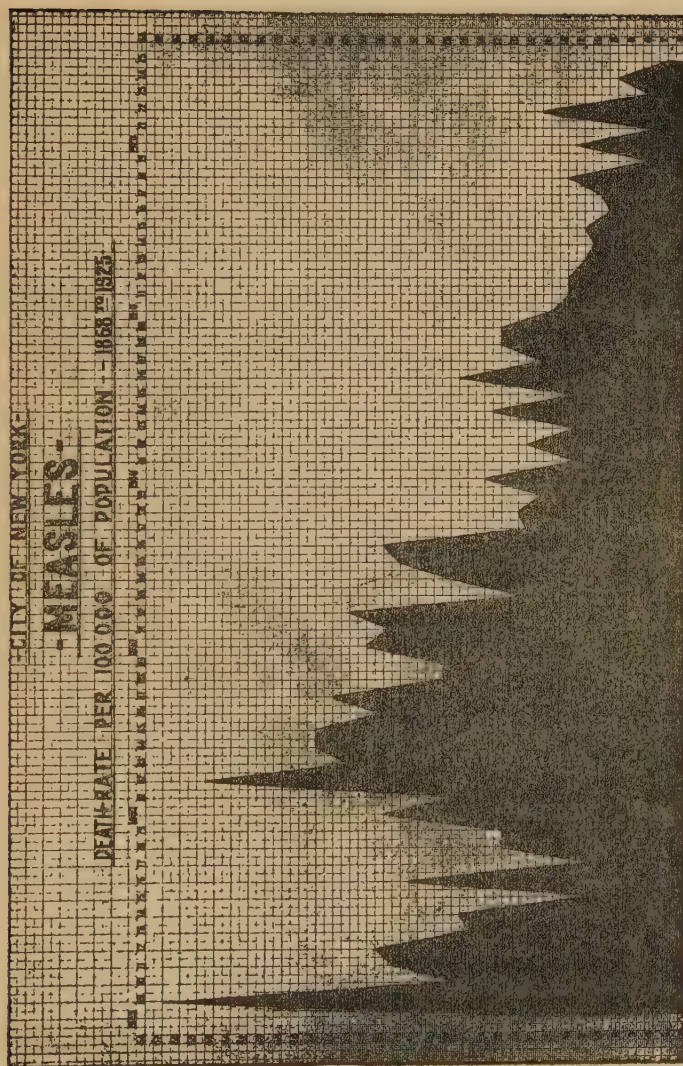
Treatment of the Sick No Secret

The effort of medical science to treat and reduce sickness is based on accurate observations of a multitude of carefully studied patients in office and hospital. Patients in hospital are compared, to see what recoveries occur without medicine, what happens with reputedly good medicine, in what instances some medicines do harm. The doctors report upon each patient in great detail.

They discuss the results of treatment among themselves and record their conclusions for the benefit of everybody. An honest doctor anywhere in the world will gladly publish for the common good his treatments, prescriptions and methods if they have been shown to be helpful. The so-called patent medicines or proprietary and quack remedies are all fraudulent. They are secret for purposes of profit from the sick. Their contents are well known to physicians. If they were worth anything they would have been used by physicians and made public. It is a part of the honor of medicine everywhere in the world that whatever is found to be good in diagnosis and treatment of human disease shall be made public. Science is not secret information: it is public truth which must be available for all. To avoid error in conclusions as to the result of treatment there must not only be accuracy in each case, but a great number of cases studied, to exclude the errors of accident.

Measurements in Public Health

I should like to show you a series of records which give briefly the history of some of the notable improvements in the control of preventable diseases. Take measles. Suppose somebody in this city, as an example of what has occurred generally in the United States, started

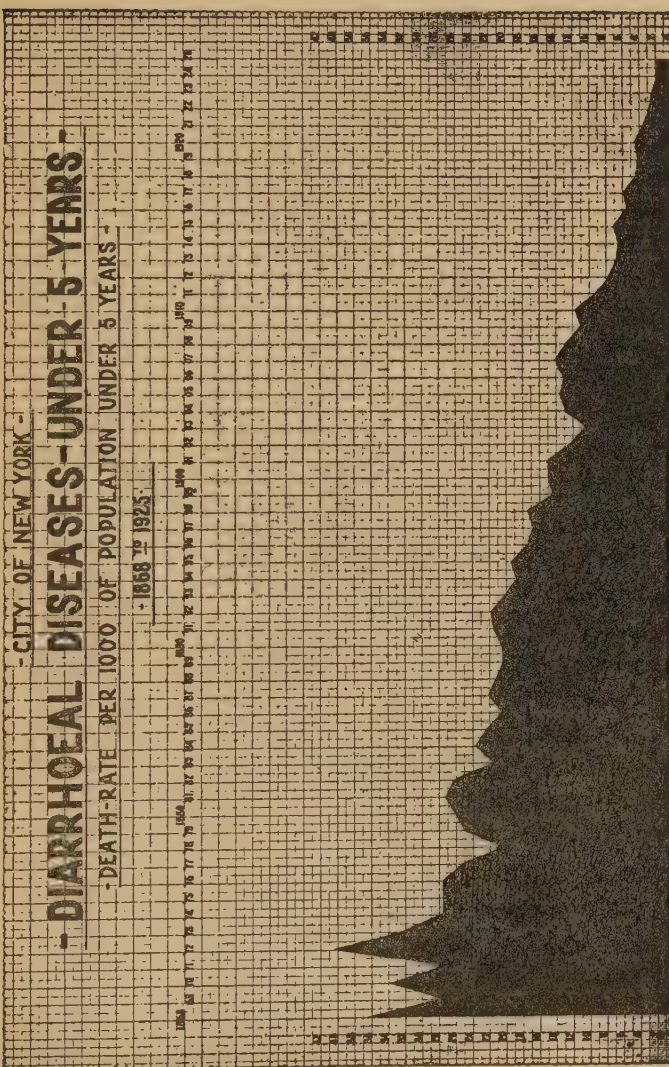


selling a certain patent medicine and said, "This will prevent measles, 25 cents a bottle, a sure cure or your money returned," and the next year there wasn't any measles in the city. If we took only one year's experience, the charlatan would seem to have been right. But observe the history of measles in large cities, and you find that it comes in waves every second year. To avoid false conclusions, continuous records over long periods are necessary. For this reason we require the reporting of cases of communicable diseases, and have offices of vital statistics.

Some of you are old enough to remember that summer complaint used to sweep away thousands of babies every year. Summer complaint or diarrhea was largely the result of dirty milk, polluted water and habits of uncleanness in homes. With clean water, pasteurized milk and visiting nurses who taught the mothers what effective cleanliness of the baby meant, a great drop has been brought about in the death rate from diarrheal diseases in children under 5 years of age from 1907 to the present time.

Typhoid Fever

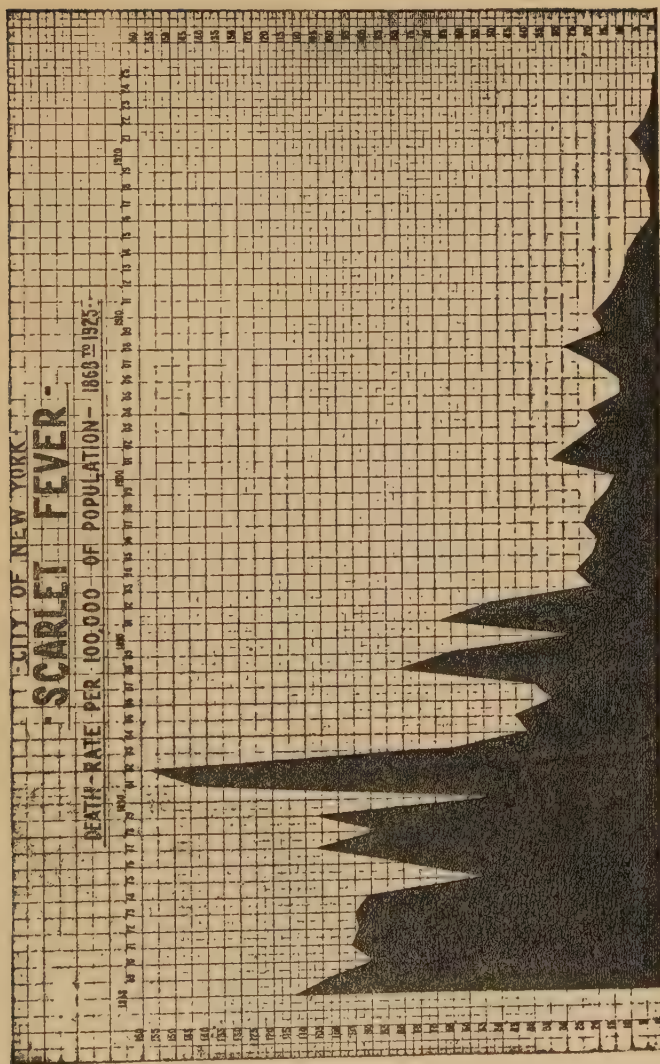
We used to have as many as 40 deaths out of every hundred thousand of the population every year from typhoid fever. In recent years there have been only about 4 per hun-



dred thousand. Last year (1925) we had in this city an outbreak of typhoid due to oysters, which affected a great many of the well-to-do in New York, but not the poor people who rarely eat raw oysters. The drop in typhoid fever has been due to the chlorination of water, the pasteurization of milk, the teaching of people who have typhoid how they can prevent its spreading in their own homes, and to the use of vaccination against typhoid, which was universal in the army during the war.

Scarlet Fever

We have now a specific serum treatment for scarlet fever, like that for diphtheria, and in another few years we expect that deaths from this communicable disease will be very rare. The death rate, formerly six or seven in the hundred thousand, has been greatly reduced, even before the new serum treatment was discovered. The careful following of one case to see that it does not spread to another, the examination of people working in milk factories to see that they have not sore throats and scarlet fever while handling the milk, the exclusion from all the dairy farms throughout the State of any person from a household where there is scarlet fever, all these measures and the practical use of the sciences of chemistry and bacteriology are of direct benefit



in reducing scarlet fever, as they have been in the case of diphtheria.

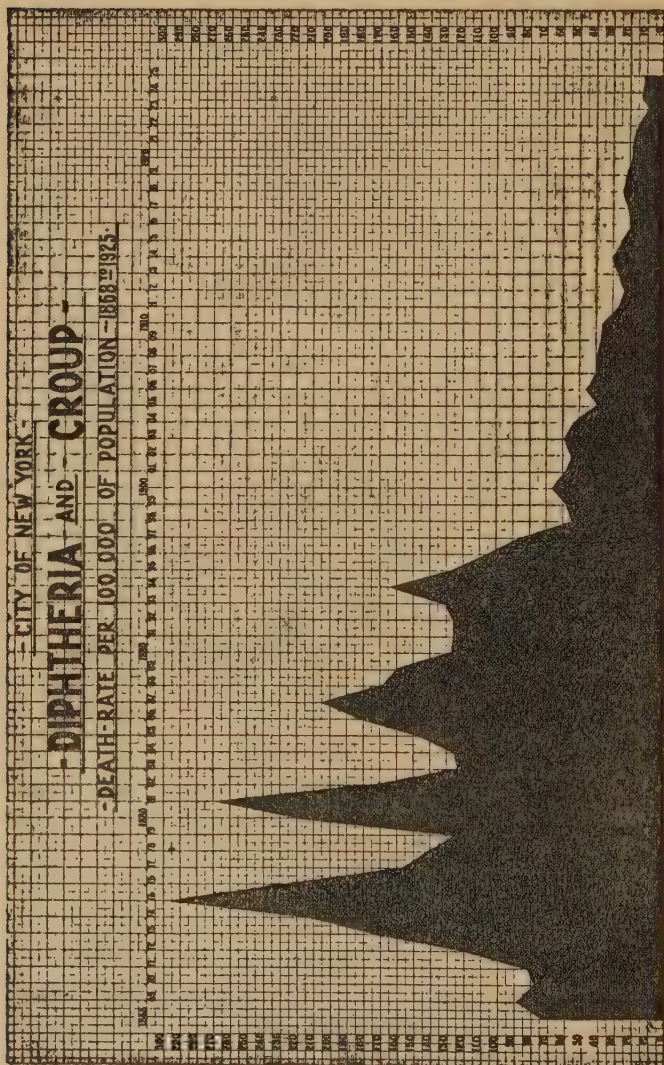
Diphtheria

This disease, within the memory of many here this evening, meant death to one third or more of those attacked. What is the situation today? Many people now regard it with no more concern than measles or chicken pox, so easy is its prevention and its detection, and so certain is its cure if treatment is prompt. It is true that children still die of diphtheria, but where this happens someone has been negligent or unobservant. The means of cure are here, but children, unfortunately, must too often pay in preventable suffering and sometimes in death for the ignorance and prejudices of their elders concerning the importance of sore throats, anti-toxin treatment, isolation and quarantine regulations.

Anti-toxins

The conquest of this disease is a comparatively recent achievement. It represents one of the concrete and highly creditable results of the period in our medical history that began some fifty years ago when Louis Pasteur and Robert Koch brought the methods of experimental science to bear on the

problems of medicine. It was a student of Koch, Frederick Loeffler, who discovered the bacillus that causes the disease, while Émile Roux, a pupil of Pasteur, demonstrated that in this disease the tissues are injured by a poison, or a toxin, given off by the bacilli and distributed by the blood. By growing some of the bacteria in a broth and then filtering out the germ-free liquid, it was found that a drop of this clear liquid injected in rabbits and guinea pigs would produce the symptoms of diphtheria poisoning. Through further experiments on guinea pigs, Emil Behring succeeded in showing that recovery from the disease is due to certain changes in the blood that counteract the poison. By 1895 Behring and other investigators perfected a method for producing this counteracting substance known as anti-toxin on a large scale, ready to use in treatment of diphtheria patients, and from that year the death rate from diphtheria has fallen steadily. In New York City, the death rate per 100,000 population has dropped from 110 in 1895 to 10 in 1925. Stated in terms of number of deaths per 100 cases of the disease, we note the striking reduction from 35 to 7 deaths. We are quite sure that the number of deaths from diphtheria can be further reduced, and possibly entirely eliminated, if the anti-toxin is in every case administered on the first day of the disease. We know that of those who



receive anti-toxin treatment on the very first day of their illness, less than one per cent of the cases are fatal.

Immunization Against Diphtheria

But better still we know how a child may be made perfectly immune to diphtheria. We can prevent diphtheria entirely if we give a mixture of toxin and anti-toxin to every child by the time it is nine months of age. By mixing some toxin and some anti-toxin, the two partially neutralize each other so that the mixture is not injurious, while at the same time the very little dose of toxin is able to stimulate the body to produce its own anti-toxin. The first attempt to immunize children against diphtheria was made in 1913. Three doses, one week apart, are given, and the child thereby develops his own immunity to the disease, which lasts for many years and probably for life.

Tuberculosis

Science has not yet found a cure for tuberculosis in the sense that it has a cure for diphtheria, but we have found out a number of important facts about the disease and as a consequence it is yielding to control measures built upon these scientific discoveries. Tuberculosis is a germ disease. This is not a guess. The germ was discovered in 1882 by Robert Koch, a German

physician. By growing cultures of the organism which he found and then injecting these cultures into animals, he was able to prove that the organism which he had isolated was the cause of the disease. After he had satisfied himself of the correctness of his views, he published a paper describing his experiments so that other scientists might repeat them and thereby satisfy themselves that he had stated the truth.

Koch's contribution to medical science and to the control of tuberculosis is by no means limited to the discovery of the "tubercle bacillus" as the germ of tuberculosis is known. In his laboratory he developed and expanded systematic methods of cultivating, identifying and classifying bacterial diseases, and through his painstaking efforts placed the science of bacteriology upon a permanent and sound basis. When a doctor suspects tuberculosis in his patient, he obtains a sample of the patient's sputum and sends it for examination to a bacteriological laboratory, where the presence or absence of the causative organisms can be detected under the microscope. This aid to a clinical diagnosis makes possible the detection of the disease in its early stages when there is still time to save the life of the patient and to protect others from exposure to the disease.

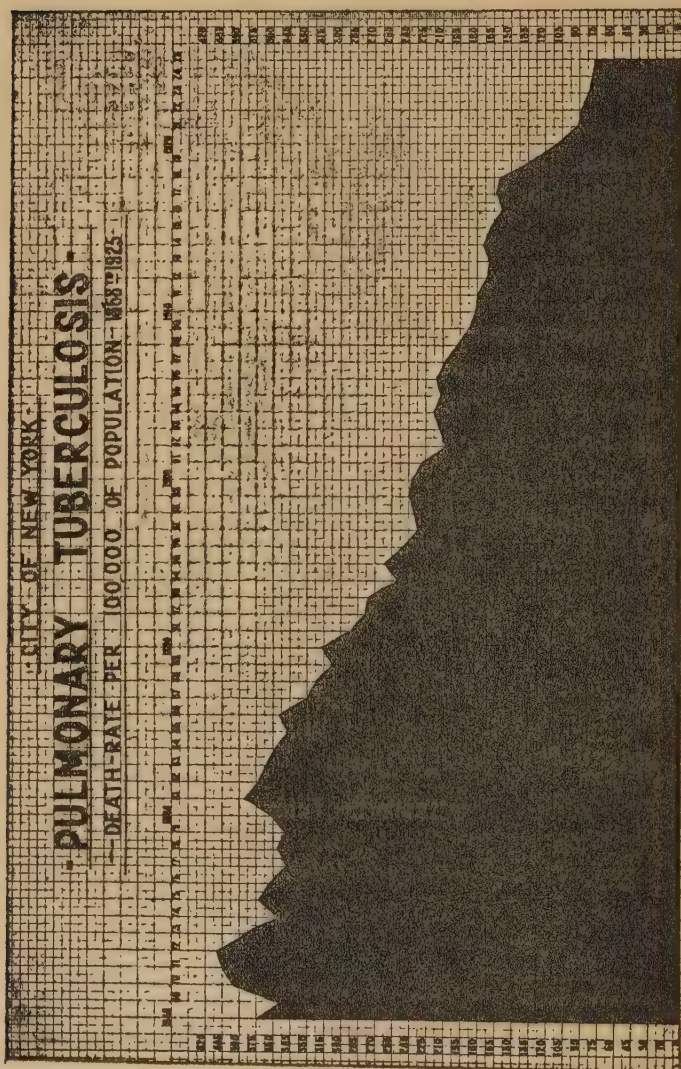
When it was recognized that tuberculosis will spread from one person to another by the sputum, and that the disease may be healed if the patient

can have rest and, if practicable, get away into the country for a while and be properly fed, a good beginning was made against its distribution, and here in New York we have now actually more beds available in our hospitals than we really need for this kind of treatment of the disease, because of the steady and marked reduction in cases of tuberculosis since these hospital beds were provided.

Preventive Work

By studying the deaths from tuberculosis according to the age and sex of the patients we learn where the chief burden of prevention lies and what remains to be done. In the wage-earning years men get tuberculosis and die of it many times more than women because they are exposed to a great many of the dusts and fumes and unsuitable conditions of industry in shops and factories and places where there is stone cutting and drilling, polishing, grinding, tool sharpening and all such activities. In all trades, dusts add to the hazard of tuberculosis.

The little children die of it because they are kept close to their mother, often sleeping in the same bed and living for the first months of their lives almost in the mother's arms. There is a period of school life when few children have the disease in a serious form, and then at the ages



from 15 years on the deaths mount and mount, until the heaviest losses are at 45 years of age.

Every death from tuberculosis is sorted and studied in our health departments as if it was the only death that was going to occur that year. We strive to learn from the loss of each life some fact of value, which will be helpful to somebody else in preventing disease. When we study the deaths according to the patient's place of residence, we find a marked difference in the death rates from tuberculosis because of variations in the wealth, housing, intelligence, occupation and race of various groups of people concerned. A quarter of a century ago, the death rate from tuberculosis in New York City was more than 200 per 100,000 population. In 1924 the rate was 91. A few years ago, tuberculosis was the leading cause of death. Today, in this city, it is fourth, being exceeded by heart disease, pneumonia and cancer.

Positive Health

Health is not only the absence of disease, freedom from defect or postponement of death. It is a positive accomplishment in which we enjoy and use to the full in happiness and strength the well controlled powers passed on to us with the gift of life.

Great additions to the length and quality of

healthy living have been made chiefly through the labors of men and women who have devoted their years of industry to solving some of the problems which our heredity, our material surroundings and our social organization have developed. Physicians as practioneers of medicine and surgery among the sick, and as officers of health in our cities, counties and states are the agents through whom the useful application of the sciences is made for safety of life and for the health of all of us.

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